



The Blast Furnace and Steel Plant

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The Blast Furnace *and* Steel Plant

Vol. X

PITTSBURGH, PA., DECEMBER, 1922

No 12

Mills Built for Rolling Nickel and Monel

Brief Description of the Refining Process and of the New Rolling Mills at Huntington, W. Va.—Physical Properties of Monel Metal.

THE engineering profession, and the steel industry both owe a debt of untold proportions to nickel. In its many forms, pure and in alloys, it has made simple, many problems otherwise difficult or impos-

sible of solution. Today, nickel is a definite necessity.

So universal has its use become that an entire industry has developed to keep pace with the demands for its production. As investigation after investiga-

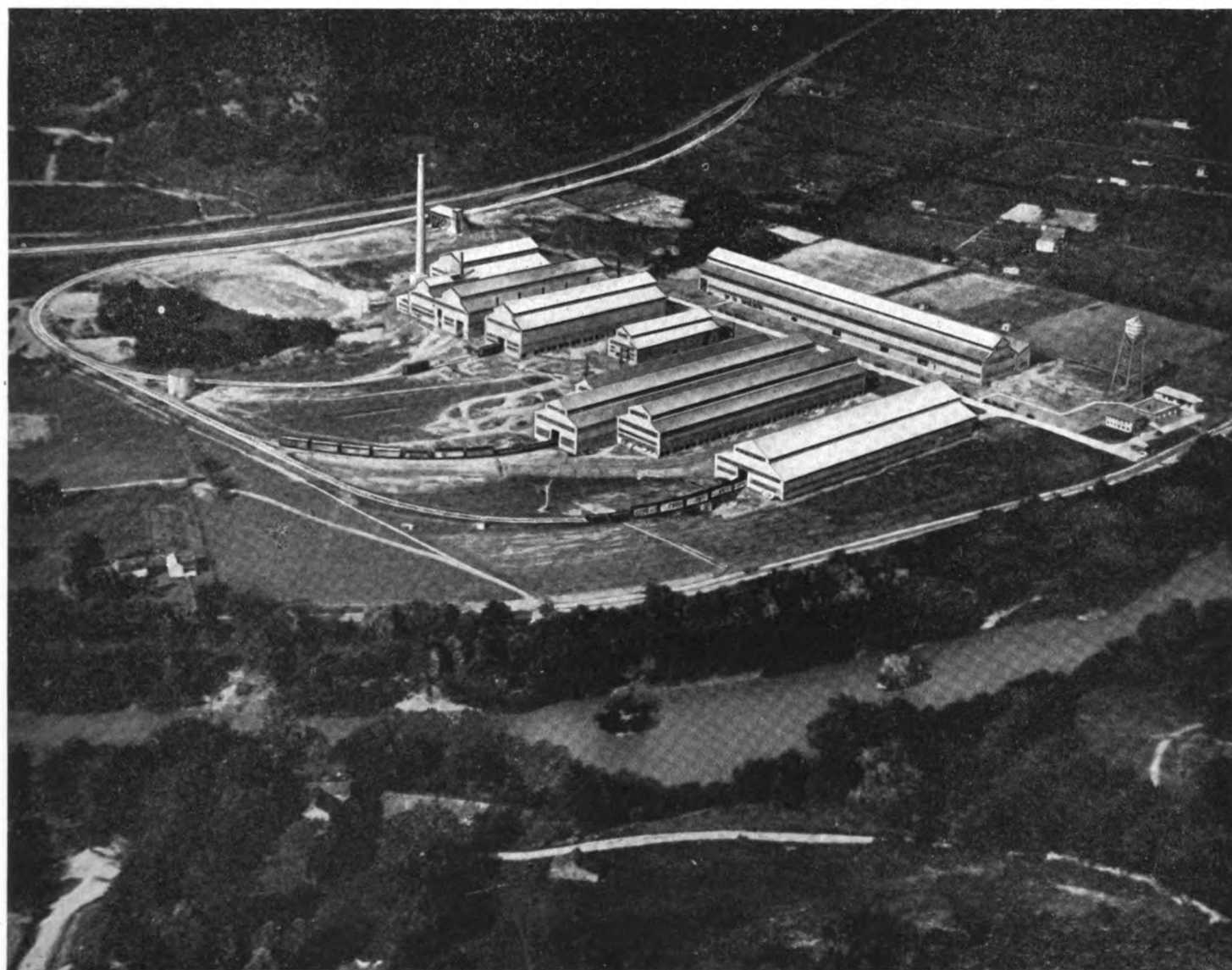


Fig. 1—An aeroplane view of the new rolling mill plant. In the foreground is shown a bend of the Guyandotte River, tributary to the Ohio. The group of parallel buildings in the main foreground constitute the calcining department in which the monel matter is converted into metal. At right angles to the calcining buildings is shown the rolling mill building. The main line of the Chesapeake & Ohio Railroad is shown in the background.

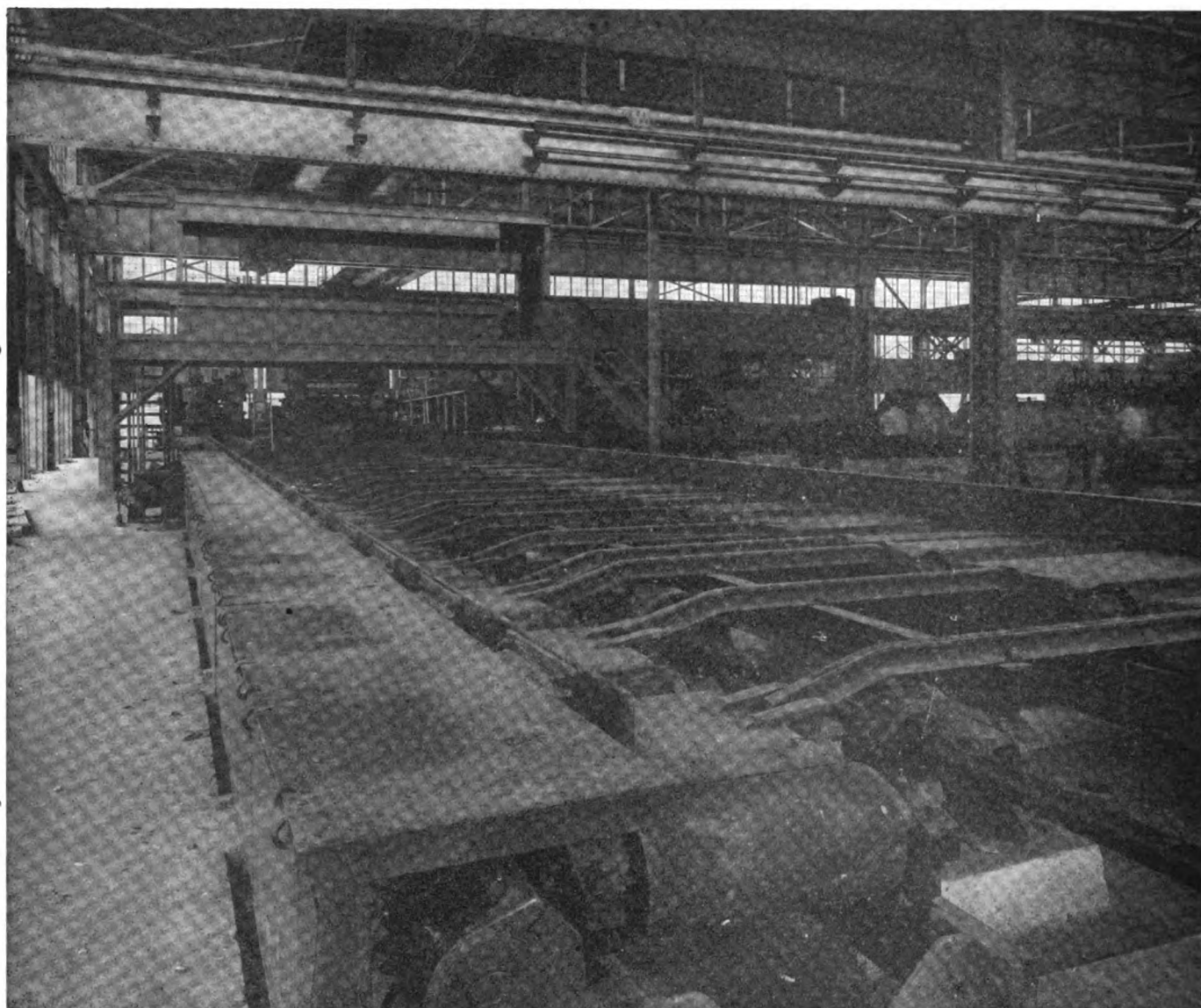


Fig. 2—The 24-in. merchant mill in which the billets of monel metal are reduced to sheet bars. The entire mill is controlled electrically by one man standing in the pulpit shown in the background. The heated billets are delivered by an electric charging machine from gas-fired furnaces which do not appear in the photograph. In the background at the right is shown the special electrical control for both the merchant mill and the rod mill, part of which appears in the right-hand background of the photograph.

tion has disclosed new and broader applications for nickel and its combinations particularly monel metal, greater and greater facilities have arisen for its production and manufacture. The latest chapter in the romance, begun in 1884, when the copper nickel deposit near Sudbury, Ontario, was discovered in the construction of the Canadian Pacific Railroad through that province, opens with the completion and actual operation of the group of rolling mills at Huntington, West Virginia. These mills, completely modern, the last word in rolling mill practice, complete the sequence of operations by which the International Nickel Company, from the ore in the mine to the finished sheet or rod or wire, are enabled to deliver the product made entirely under their own supervision, and in their own plants.

Both malleable nickel and monel metal are now under production. Many difficulties had been encountered, for rolling steel is one thing and rolling nickel or monel is another; what seemed an entirely similar operation, differs widely in important details,

and men trained in steel mill practice had to re-adapt their experience to monel practice. That can best be done in a plant designed for the purpose, as experience has shown.

The plant is located at Huntington, W. Va. This site was selected after a very careful investigation of the many advantages claimed for various industrial centers. Huntington combines the many basic factors, which experience has shown are necessary for monel and nickel sheet production. Intelligent labor has provided excellent home environment. Adequate electric power is supplied by the Virginia Power Company, over high tension transmission lines from its main generating station about 60 miles distant. Contiguous high-quality coal and natural gas, both essential to the heavy heating requirements throughout the processes are furnished over unexcelled transportation facilities, offered by the Ohio River by water, and the main lines of the Chesapeake & Ohio and the Baltimore & Ohio Railroads, while natural gas is adequately supplied from local fields.

Fig. 1 shows an aeroplane view of the plant and its location. Some 80 acres, about $3\frac{1}{2}$ miles south of the city, directly adjoining the C. & O. main line tracks, are occupied. The mills are really divided into two parts. The calcining department is located in the foreground in which the monel or nickel matte is converted into metal, and the sheet mill at right angles to it, where are located the rolling mills, the heating furnaces, annealing furnaces, shears, etc.

Monel metal and nickel are so often spoken of in such general terms that a brief glance at the complete process, or chain of processes may be interesting. The ore, stop-mined at present depths of approximately 1,200 ft., consists of pyrrhotite, with chalcopryite and pentlandite, together with a basic gangue material. These sulphide ores are roasted to reduce the sulphur to a working average, then smelted in a blast furnace to a matte containing approximately 24 per cent nickel, plus copper, 45 per cent iron and the balance sulphur. This matte is then blown in a converter, similar to the familiar Bessemer steel operation, to a matte containing essentially nickel, copper and sulphur, which is ready for refining.

This Bessemer matte, which carries approximately 55 per cent nickel and 24 per cent copper is refined by the Orford process, which is the oldest process for the separation of copper and nickel. The Bessemer matte is melted with salt cake, or niter cake, together with coke, in the blast furnace. The sodium sulphide formed by the reduction of the sodium sulphate by the coke, together with the copper sulphide, forms a matte of

low specific gravity. The product of the blast furnace is allowed to cool in pots, in which a separation occurs, the upper portion or "tops" containing the greater part of the copper sulphide together with the sodium sulphide, the lower portion or "bottoms" containing the greater part of the nickel sulphide. The "tops" and "bottoms" are readily split apart when cold. Several treatments are required to effect a sufficiently complete separation. The "tops" go to the copper cupola and converter, where they are blown to blister copper. The "bottoms," consisting, essentially, of nickel sulphide or matte, are roasted and leached alternately until they have been completely changed to nickel oxide. This is reduced with charcoal in crucibles or reverberatory furnaces to metallic nickel at a temperature above its melting point, so that the resulting product may be cast into pigs. The waste heat from the latter battery of furnaces is utilized to fire large boilers which will supply the ordinary steam requirements of the four large hammers. As a standby for the latter, natural gas fired boilers are installed in the hammer shop.

From the reverberatory furnaces the metal in the form of pigs goes to the electric furnaces where it is remelted and cast in the form of ingots, or blocks, or poured into water to form shot. Electrolytic nickel is also produced by casting this reduced metal at once into anodes and obtaining pure nickel cathodes from them by electrolysis with an electrolyte of nickel sulphate.

The equipment in this department consists of one

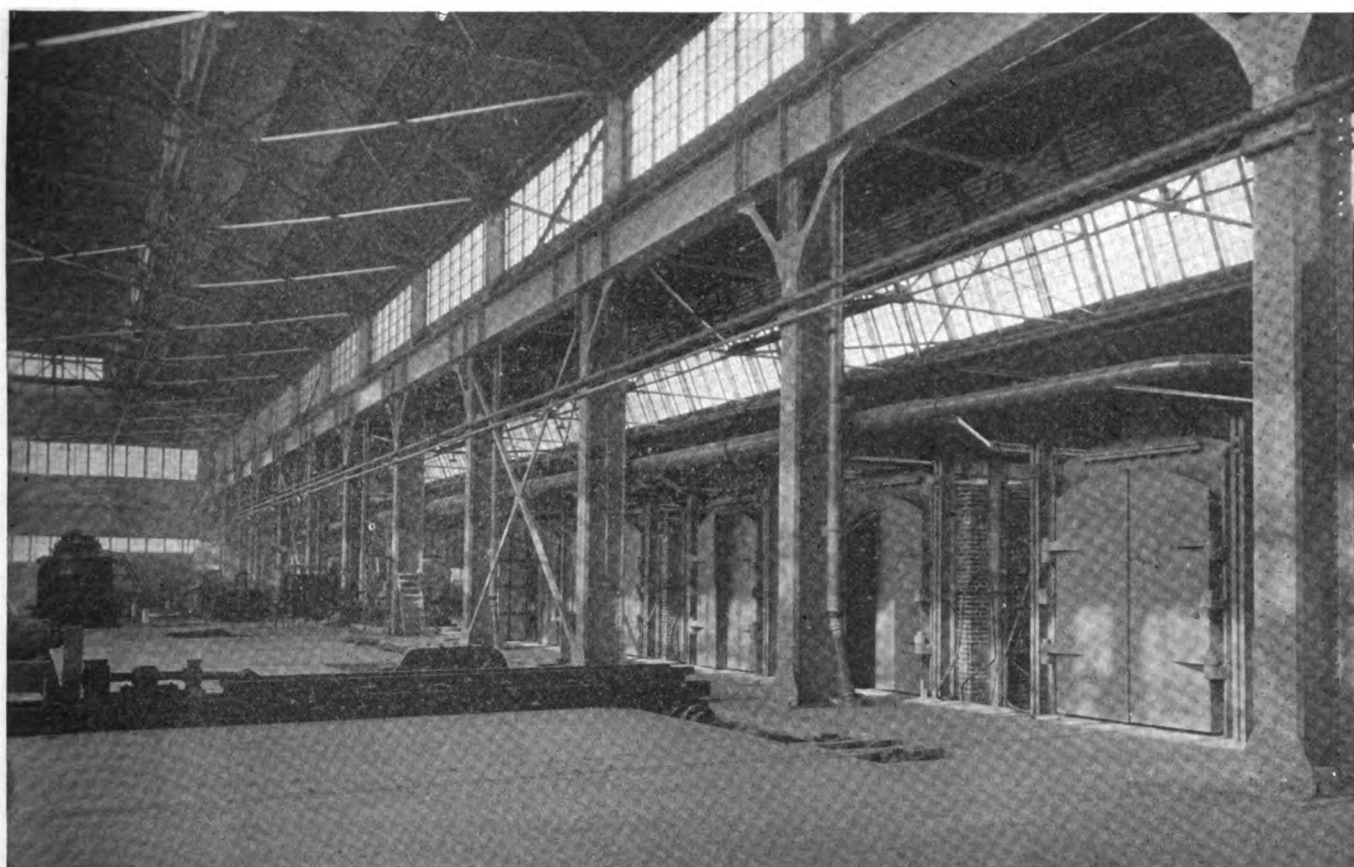


Fig. 3—Battery of surface combustion annealing furnaces for monel metal sheets, forming an important part of the sheet mill equipment of the new rolling mills at Huntington, W. Va. Like all of the other furnaces in the new mills, these are fired by natural gas. The large sheets are placed in cast iron boxes, sealed against the air, similar to the process of sheet steel annealing. One of these boxes with its load of monel metal sheets weighs 30 tons. They are inserted and withdrawn from the furnace by a special electric charging machine, part of which appears in the foreground of the photograph.

3-ton Moore electric furnace and one 7-ton Heroult electric furnace, so that its present capacity is in excess of that of the remaining departments as at present equipped, while provision has also been made for the installation of further electric furnace units as required. So far as refining in electric furnaces and ingot casting are concerned, the handling of monel metal in this department does not differ materially from the usual steel mill practice.

Number of Special Operations.

In the next step in its reduction to commercial form, a number of operations are involved that are entirely lacking in steel processing. In the case of steel, the ingot goes directly to the soaking pit, the time required for this part of the process is short and involves little additional expense as compared with the time and processes through which the monel metal ingots must go after leaving the ingot mold and before they can be delivered to the rolling mill. Steel is a metal very susceptible to oxidation and surface defects on the ingots are automatically removed by the heating and rolling processes in which the oxidation scales off, leaving clean metal. Monel metal, on the other hand, is highly resistant to oxidation so that it is necessary to remove the outer skin of the ingot completely with its accompanying surface defects before proceeding to the heating and rolling.

Consisting chiefly of nickel and copper as it does, the metallurgy of monel metal is radically different from that of steel so that its successful production is naturally a highly specialized undertaking which can

only be carried out by skilled men experienced in its handling. In the course of manufacture up to this point, certain defects, or oxides, are allowed to remain in the ingot. These oxides do not combine chemically with the metal but appear on or close to the surface of the ingot as physical defects. These defects, however, must be removed before the metal can undergo any further processes.

The ingots are accordingly taken to milling machines where a heavy cut is taken off each side. As an extra precaution to insure satisfactory quality the milled ingots are examined and any defects remaining are chipped out with pneumatic hammers.

Equipment Provided on a Liberal Scale.

After the chipping processes the ingots go back to another battery of furnaces in the hammer department, where they are clogged down to bloom size. The steam hammers employed in this department range from eight ton capacity down to 1,500 pounds, so that ample provision is at hand for the making of special forgings of monel metal or nickel, in addition to the usual production of monel metal blooms for the rolling mill itself.

After heating in the battery of furnaces in the rolling mill department itself, these billets go to the 24-inch merchant mill for conversion into sheet bars, or to the rod mill. So far as the actual handling of monel metal is concerned, either in the merchant or the rod mill, or in its subsequent reduction in the sheet mills in another unit, there is no apparent difference between its production and that of steel. With

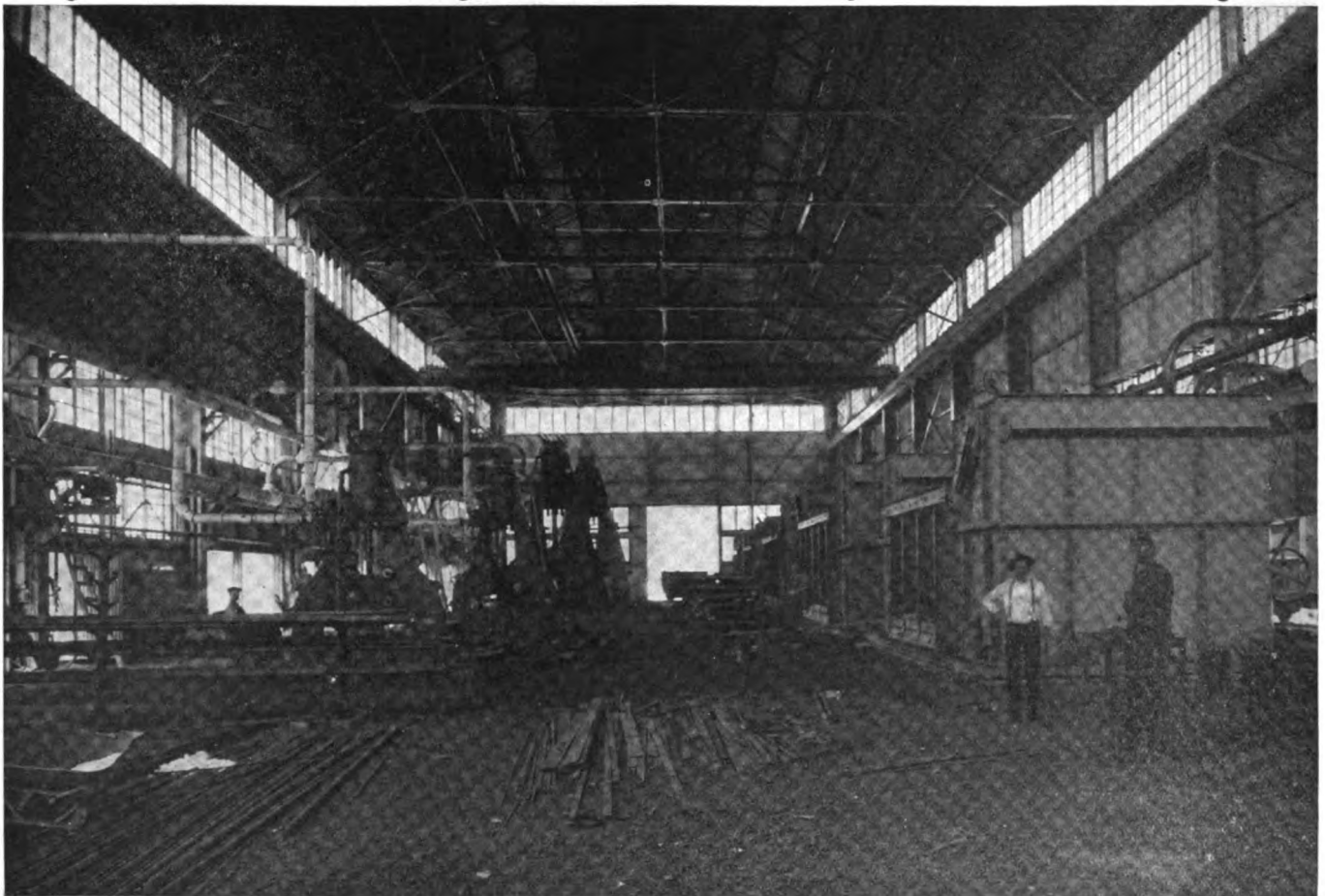


Fig. 4—View of the hammer shop and its batteries of Stevens regenerative gas fired furnaces. The four hammers range from 1500 pounds capacity in the foreground to the 8-ton hammer at the end of the line. In the latter the monel metal ingots are clogged or reduced from ingots to blooms.

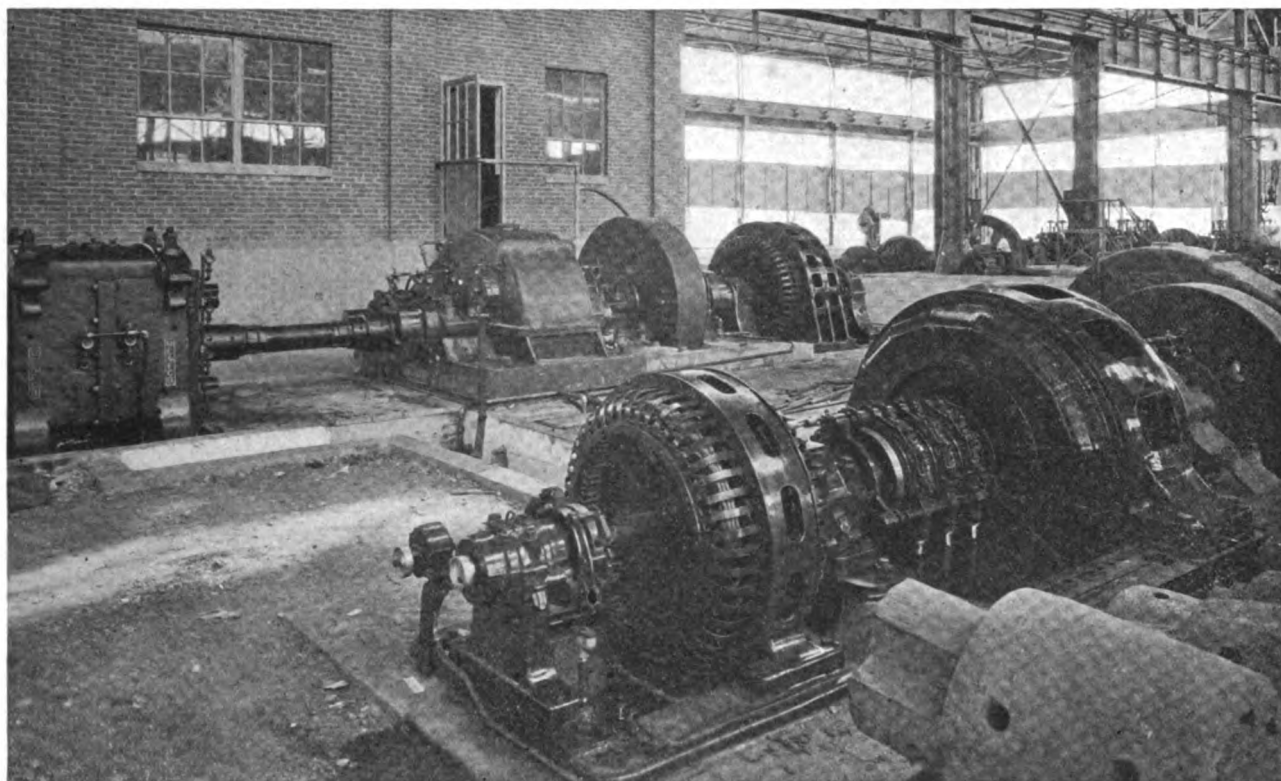


Fig. 5—The control house for the merchant and the rod mills, showing in the background part of the electric drive for the 24-in. merchant mill and in the foreground the special form of drive designed by General Electric and Westinghouse engineers for the rod mill. A rod mill consists of a series of units tapering down from the largest to the smallest and the speed of each unit must vary in accordance to the size of the rod it rolls.

a metal consisting chiefly of nickel and copper the greatest problems are naturally involved in the heating of it and this is equally true in every step of the process from the calcining furnace to the final annealing processes.

Some Features of the Sheet Mill.

The bars from the merchant mill go to the sheet mill which is a most complete, specially designed plant for the production of monel metal sheets and which will do more to overcome the difficulties in providing an adequate supply of monel metal sheets than has been possible up to this time, since a very large part of the production difficulties have had to do with the rolling of sheets. In this department, as is also true of all of the others, while equipment has already been installed with a capacity far in excess of the actual requirements, ample provision has also been allowed for expansion and the installation of additional units whenever required, so that with an ample supply of high grade metal direct from its own furnaces and rolling mills, the International Nickel Company will be in a position to maintain adequate stock of all sizes and gauges of monel metal sheets at the warehouses of various distributors in different parts of the country from now on.

Grinding machinery has been installed to make it possible to deliver monel metal and nickel sheets ground to a good surface so that a wide range of articles may be produced from these sheets with the minimum amount of buffing in the finished form.

So far as a detailed description of the buildings and equipment is concerned, probably a very much better idea of this can be obtained from the photographs and will likewise be found considerably more inter-

esting. It will be noted throughout that electric unit drive is employed on every machine and that the controls for the large rolling mill units are protected by special compartments, or houses, raised several feet above the floors or rolling mill itself. Numerous advances over current rolling mill practice have been incorporated in these control units, this being true in particular of one control of the rod mill in which the speed varies from 450 to 100 rpm.

The series of units comprising the rod mill is driven by a 400-hp., a.c. motor and a smaller d.c. motor, both of which work in conjunction with a highly specialized control system to give the great range of speed required. The necessary controls are installed in a small brick house as will be noted in several of the accompanying photographs. While these pictures show the mills in a more or less unfinished condition before production operations had actually been undertaken, they serve to give a very good idea of its size, completeness and ultimate capacity. It will be noted that in every department ample provision has been made for expansion by the addition of extra units, although as stated previously, with the equipment already installed and now in operation, the capacity far exceeds the present requirements. While the demand has showed a very marked increase since the beginning of the year, the capacity of the new mills at Huntington will be sufficient to meet all calls for sheets and rods as well as forging and special work, and at the same time permit of local stock in the warehouses of distributors.

Completely Equipped Laboratories.

With a natural alloy of such unusual and distinctive physical properties as monel metal, it goes with-



Fig. 6—View of the sheet mill looking toward the north end. The battery of heating furnaces for the sheet bars is located at the left and does not appear in the photograph, while the annealing furnaces shown in a previous photograph are further back on the same side of the building. The second unit of the sheet mill appears in the background, but it is difficult to give any idea of the extent of the equipment of a single building of this size in a photograph.

out saying that the most important units at the new mills are the laboratories. They are permanently housed in a building specially planned for this purpose and completely equipped for carrying out chemical and physical tests of every nature. Both in the reduction of the matte to monel metal in a great number of commercial forms and in its application in a wide variety of manufacturing processes, problems are constantly arising. The staff of the laboratories at the Huntington mills is at the service of manufacturers in solving these problems, as is also that of the research department of the International Nickel Company. In



Fig. 7—Completely equipped chemical and physical laboratories which form a very important part of the new rolling mills of the International Nickel Company at Huntington, W. Va.

the course of more than 15 years' work of this nature, a vast amount of data has been accumulated so that frequently what appears to be a difficult problem to a manufacturer is already a matter of actual experience. The benefits of this experience are at your disposal.

Range of Products

Both monel metal and nickel will be produced at

the new Huntington mills in the form of rods from 7/32-in. up to 12-in. round, square or hexagonal and in sheets from .018 to 1/4-in. These sheets will be rolled in all sizes commonly supplied in sheet steel. Special forgings in either monel metal or nickel can also be furnished.

Personnel of the Organization.

For years the Nickel Company has been gathering together a technical operating organization capable of visualizing the magnitude and importance of the many problems and possibilities of this specialized industry. The steel industry furnished many. Ambrose Monel, whose name indicates the conception that nickel and copper would be refined (without separation) into an alloy of tremendous value, went from Homestead Steel as did Bostwick and others.

Today the organization headed by Mr. Robert C. Stanley, a veteran in the company, of whom it is said, no other man ever held a like number of positions from the bottom up, is keenly alert to every development that definite research into each industrial avenue brings to light.

The Research Departments are under the direction of Mr. A. J. Wadhams, assisted by Dr. Paul D. Merica, formerly of the U. S. Bureau of Standards, working in conjunction with Dr. J. F. Thompson, head of the Technical Department. Dr. Thompson has devoted many years to the study of nickel alloys and his papers before engineering societies and published articles on kindred subjects are well known. In addition, the Sales and Publicity Departments, headed by Mr. J. F. McNamara, with his corps of investigating specialists, are constantly solving the problems of manufactures of innumerable products, where the special virtue of nickel and monel offer an application.

Backed by such an organization, it is not surprising that Mr. A. S. Shoffstall, General Manager of the Hunt-

intgon mills, and Mr. H. M. Brown, the Mechanical Engineer, look forward to uninterrupted production records, that will fully keep pace with the anticipated revival of the steel and metal working industries.

The physical properties of monel may be of reference value.

PHYSICAL PROPERTIES OF MONEL METAL

Melting Point	1360° C. (2480° F.)
Specific Gravity (Cast).....	8.87
Weight Per Cu. In. (Cast).....	0.320 Lbs.
Weight Per Cu. In. (Rolled).....	0.323 Lbs.

Coefficient of Expansion:

(25° C—100° C).....	0.000014 Per 1° C.
(25° C—300° C).....	0.000015 Per 1° C.
(300° C—600° C).....	0.000017 Per 1° C.

Electrical Resistivity.....	256 Ohms Per Mil-Ft.
	42 Microhms Per Cm.

(Temp. Coefficient.....)	0.0011 Per 1° F.)
Electrical Conductivity.....	4% (Copper 100%)
Optical Reflectivity.....	.60% of Silver
Heat Conductivity.....	1/15 that of Copper
Shrinkage	¼ Inch per Foot
Hardness Cast Material.....	20-23 (Shore Scleroscope)

Hardness Hot Rolled Rods:

27 (Average Shore Scleroscope).

Hardness (Brinell, 3,000 Kg.).

Hot Rolled Rods.....	162
Cold Drawn Rods.....	160-245
Castings	115

Modulus of Elasticity (Young's).....25,000,000

Thermal Conductivity:

0.06 Calories Per 1° C. Per Second Per Cm³.

True Specific Heat:

0.109 Calories Per Gram Per 1° C.

Magnetic Induction for H = 100.....1,500 Gausses

Energy Absorption:

Izod Test	115
Charpy Test	160
Toughness	1580
Heat Treated Carbon Steel (S. A. E. 1045).....	920

Torsional Tests on Rods (Average).

Shearing Stress—Lbs. Per Sq. In. on Remotest Fibres:

At Elastic Limit.....	31,796 Lbs. Per Sq. In.
At Ultimate Load.....	79,053 Lbs. Per Sq. In.

Tensile Tests on Castings:

Yield Point	37,093 Lbs. Per Sq. In.
Tensile Strength	72,281 Lbs. Per Sq. In.
Elongation in 2 Inches.....	34%
Reduction of Area.....	32%

Tensile Tests on Sheets:

Yield Point	25,000 Lbs. Per Sq. In.
Tensile Strength	65,000 Lbs. Per Sq. In.
Elongation in 2 Inches.....	35%

Tensile Tests on Hot Rolled Rods:

Rounds and Squares	Yield Point Lbs. Sq. In.	Ult. Ten. Str. Lbs. Sq. In.	Elong'n in 2 In.
Up to 1"	63,126	94,562	40%
1 1/16" to 1 11/16" Inc.....	61,963	93,104	39%
1 3/4" to 2 7/16" Inc.....	50,115	87,678	42%
2 1/2" to 3 1/2" Inc.....	43,805	85,282	44%
Over 3 1/2"	47,335	84,763	43%
Rectangles	56,353	85,562	42%
Hexagons	60,736	87,781	40%
Proportional Limit	35,000 to 45,000 Lbs. Per Sq. In.		

Compression Tests on Hot Rolled Rods:

Elastic Limit.....	45,000 to 50,000 Lbs. Per Sq. In.
Yield Point.....	67,000 Lbs. Per Sq. In.

The tensile strength of Monel Metal wire varies from 80,000 pounds per square inch to 150,000 pounds per square inch, depending on the temper.

Shear Tests on Hot Rolled Monel Metal Rods 1 1/8" Round:

Diam. of Test Piece	Single Shear Stress Lbs. Per Sq. In.	Double Shear Stress Lbs. Per Sq. In.
1"	61,092	127,200
3/4"	49,883	103,267
	1" Round	
1"	55,163	115,500
3/4"	44,806	90,163

The general properties of pure nickel parallel monel very closely, differing slightly under special conditions, each has its particular advantages for specific use.

THE BUDGET

Much has been written recently on the mechanics and machinery of the budget in private enterprise, but little has been said about the spirit behind the budget.

"It is this spirit behind the budget," says E. W. McCullough, manager of the Fabricated Production Department of the Chamber of Commerce of the United States, "which, in the last analysis, will determine whether the forms and procedure of budgetary control shall have meaning and usefulness, or whether they shall mean but another addition to the administrative red tape now cluttering business.

Mr. McCullough deals with this phase of the subject in a bulletin which his department has just issued under the title, "Budgeting for Business Control."

"The first point in a reasonable financial program," says Mr. McCullough, "is to aim for that amount of business within one's resources to handle which will give a fair return and which is founded upon a conservative view of the real demands of the consumer.

"The second is to strive to make the most of capital resources; establishing a production system; by refraining from plunging into expenditure for new plants and equipment where the old will serve the purpose; by placing collections on a reasonably prompt basis; by having purchases in line with production and sales programs and by refusing to act as a free warehouseman.

"The third is to regulate current borrowings in such a way that they will be well under control. As the business of a firm expands, the lag between the order and payment date increases, bringing with it a growing need for banking accommodations. These banking requirements are usually granted, for the increase of business is a warrant of the success of the enterprise. New loans are made and old ones are renewed and extended, until almost insidiously grows the conviction on the part of the manufacturer that the short term accommodations are a fixed contribution to the capital of his business, and he acts and works upon this assumption. Inevitably, the day comes when the bank finds itself pressed for funds and, in turn, calls on the manufacturer for payment, and since such a demand usually comes at a time of business depression, the manufacturer finds himself unable to liquidate. Then very likely reorganization ensues, resulting at best in the short term funds becoming, upon onerous terms, a part of the funded or long term obligations.

"For all lines, seasonal and non-seasonal, it should be clearly realized that short time obligations are not a permanent contribution to capital and that manufacturers should hold themselves in readiness to liquidate accounts receivable over current indebtedness. Short term obligations should bear a definite relationship to the capital."

The Manufacture of Fine Forging Steels

Electric Furnace Practice, Casting Methods, Raw Materials Used.
Heat Logs for Carbon, Chromium and Nickel Chromium Steels.

By LARRY J. BARTON*

WAR time conditions of hasty production are a thing of the long gone past, the period of depression is gradually going, and American manufacturers are gradually awakening to the fact that if they are to meet low priced foreign competition it must be upon the greater merit of their higher priced product. Production is going ahead by leaps and bounds and again the call is coming forth for high grade forging steels. The writer offers the following treatise for the possible help manufacturers may obtain, the results and practice given being those following experiments and tests covering an extensive period, and accepted over others as superior, both from the standpoint of quality and their commercial costs. For ordinary grades of forging stock the cost of electric melting and refining is too high to compete with the open hearth furnace, in which very fine steel can be made. In such industries as the automotive—covering automobiles, aeroplanes and tractors; the railroad, both steam power and electric driven; and the general machine and equipment, covering all machines using reciprocating or fast moving parts, the trend is towards lighter weight forgings. In order to sufficiently meet the ever increasing strength and ductility specifications a superior grade of steel must be used. Then, when it is considered that the sections are always becoming smaller, the highest quality of steel is needed to meet the demand.

This has encouraged the electric furnace manufacturers of high quality steels, for it is only by this method of operation that many difficult specifications can be adequately satisfied. Heat treating and research have developed many properties of the alloy steels which were unknown a few years ago, giving rise to an increased market and demand for this class of work. Alloy steel castings in the heat treated condition are rapidly replacing forgings in many cases. This paper covers only the making of the ingot and its further operations, but the same furnace practice is applicable to making alloy steel castings with slight modifications such as any metallurgist will readily recognize.

While it is appreciated that very fine steels have been, and are still being made in the acid electric furnace, I do not believe they can compete with the basic electric on a highest quality basis. There are so many small points where the basic process shows its superiority that it is needless to mention them, this subject having been thoroughly covered by much more able men than the writer. The following processes will, therefore, be considered as covering basic operation. No class of electric furnace is mentioned, as all, when properly operated, will thoroughly meet conditions when considered from the strict metallurgical view. The same follows of ladles, refractories, treating equipment, etc.

*Consulting Metallurgical Engr., Los Angeles, Calif.

Proper Care of Furnace to Obtain Maximum Results.

The Hearth—One of the greatest troubles in obtaining a very high grade and uniform product consistently is with the furnace bottom. Alloy steels require a longer time in the furnace than any other class of metal, throwing a greater period of strain onto the hearth. In addition, some are more or less severe on the bottom, due to their erosive action, in addition to their higher melting points above that of the plain carbon alloys. It is indeed discouraging to the melter to find that at about the time he is finishing his heat the bottom starts rising in patches, often requiring instantaneous tapping and either scrapping the heat or

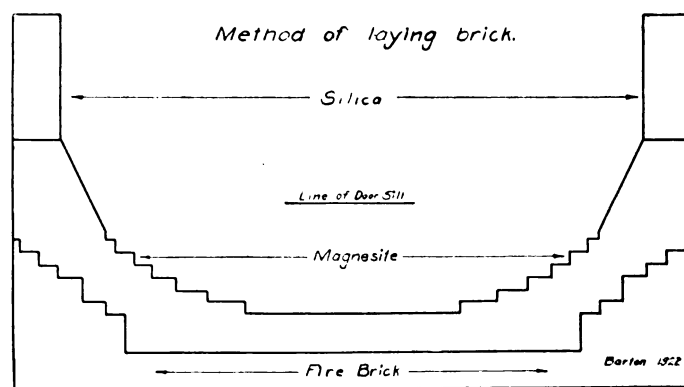


Fig. 1—Indicating the manner in which brick are laid in the furnace shell.

placing into a cheaper grade of work. This too, results in a higher cost of manufacture, and often through over zeal on the melter's part results in an inferior steel poured into a product requiring the highest grade metal obtainable, a point which works to the direct disadvantage of the shop concerned. With the idea of eliminating this point I strongly advocate the use of a hearth made by burning in the refractory bit by bit, instead of ramming and then burning. I also advocate using the best grade of dead burned magnesite obtainable for the hearth proper.

Making Bottom—The furnace shell is bricked up as per Fig. 1. Short pieces of electrode are then arranged on the bottom as shown in Figs. 2, 3, and 4. Either way is optional, depending on the size of the furnace (number of door openings), the electrodes, whether carbon or graphite, and the depth of hearth desired. Personally I like Fig. 4 better than the others as it offers better accessibility to the front of the furnace, and gives a strong support to the electrodes. Great care must be used in setting up these electrodes on bricks as a breaking apart will seriously interfere with the proper completion of this very important operation.

Basic open hearth, or blast furnace, slag in the

finely ground conditions now dusted over the bottom bricks, until all cracks are filled. This should be carefully done as it is essential to thoroughly fill any small openings with this material. A small amount is then dusted all over the bottom. The furnace is now ready to be dried out, and this operation should not be stinted. A very low gas or oil flame is inserted through one of the doors and the furnace sealed, only allowing enough air to enter to support combustion. A large amount here depends upon the judgment of the melter as to how long this flame should burn before being

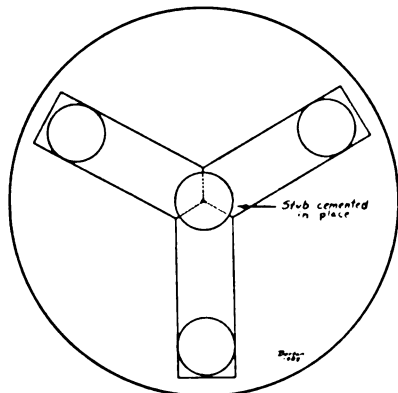


Fig. 2—Showing typical position of electrodes in furnace bottom.

raised. I recommend to burn several hours at the least until all surface moisture is driven from the furnace. The flame can now be progressively raised until in about six or eight hours the flame is burning full. The point of the flame should now be so regulated that its direct heat is thrown towards the center of the hearth. This is kept on until the furnace ceases emitting any steam from around the vent holes in the bottom and sides, and may take 24 hours or more depending upon how moist the refractories were. I have ordinarily found that about 12 to 15 hours is ample for this, but

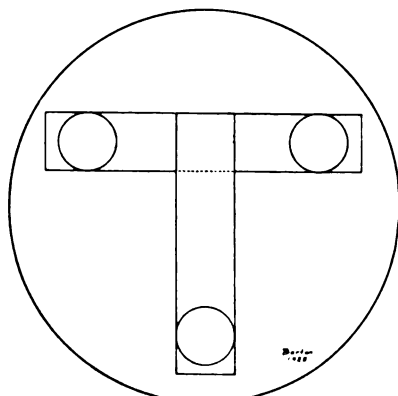


Fig. 3—A second disposition of electrodes in furnace bottom.

you must remember the old adage "better be safe than sorry." By this time the furnace walls will be a good bright red, and all preliminary expansion will have been taken up by both the roof brick and the others. Any slight spalling of either the magnesite or silica brick can now be raked from the furnace, and the actual burning begins.

The furnace electrodes are lowered until an arc is made with the hearth set-up. This is a point which should be very carefully watched for if any electrode is lowered too much there is a great possibility of it

forcing the bottom electrodes out of place causing no end of serious trouble. As all the electrodes are now at a good red heat the arc will hold steady, and the current can be thrown over to the automatic regulators. This should be held at the lowest possible figure for about an hour, and gradually raised over a period of at least four or five hours until the ground slag on the hearth is in a molten condition and running freely. The temperature should now be held at a point where the side walls are glistening, but care should be taken not to allow the silica brick to run. Magnesite, ground to about the size of wheat, can now be dusted lightly all

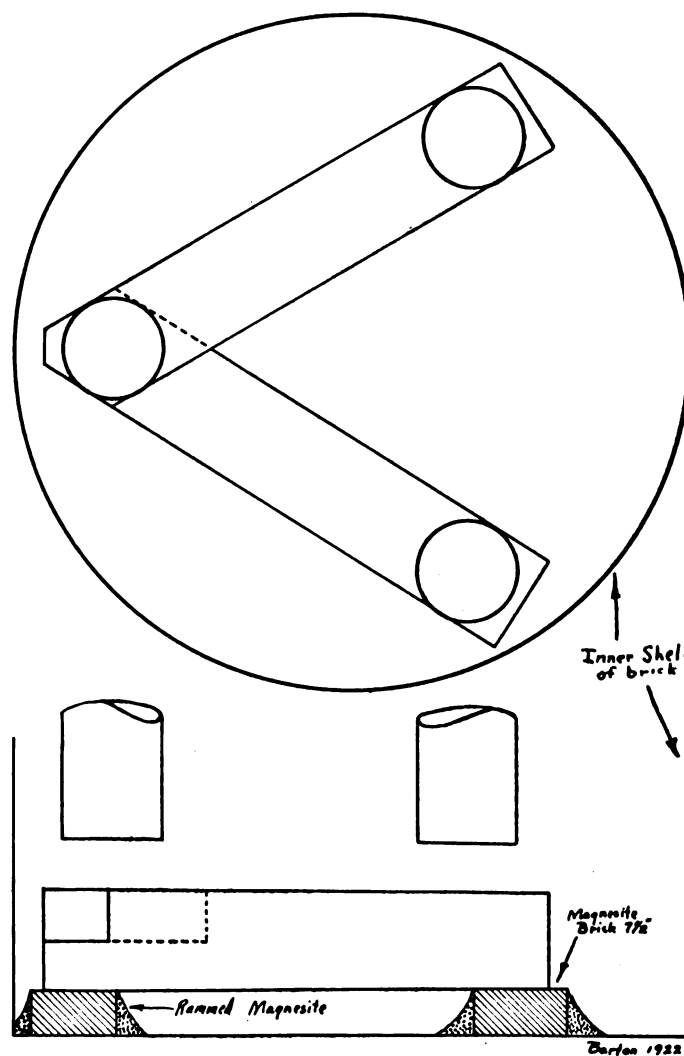


Fig. 4—A more accessible alternative for location of electrodes in furnace bottom. This arrangement shows electrodes well supported.

around, and the doors again closed. Further additions of this character can be made about every half hour, tests being taken before each addition.

The best method of taking these tests is by means of a long rod with a flattened, hoe shaped point about two inches in width. This point is pushed into the hearth material at several points, and small samples withdrawn. These samples should show thorough fusion in each case, if not, a section is unburned. During this period it may be necessary to run off load on different electrodes in order to heat one section of the furnace more than another. If trouble is had with fusion in any spot it may be necessary to dust with a small amount of your slag which will melt and run in

the crevices thoroughly binding the bottom into one compact body. I have found that a mixture of one part slag to six of magnesite offers a mixture which will give as good results as can be obtained from any set proportion, it always being necessary to change mixtures, depending on the way fusion proceeds. The hearth is gradually built up in this manner until it begins to take a definite shape. It is now good practice to tip the furnace in either direction, in order that the walls may be built up as high as possible. The sections at the jambs can be formed by using the mixture slightly moistened and tapped into shape with rables. When the final shape is obtained, as per Fig. 5, the entire hearth should be given a good dusting of slag, and the current held on until this has thoroughly melted, filling any small surface cracks or irregularities. The current is now killed, and the stubs raked from the bottom. The above series of operations should be given

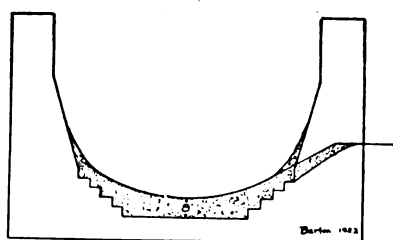


Fig. 5—Final shape of hearth before the dusting of the slag.

en plenty of time, and under no conditions should they be forced. The time for a six-ton furnace will average about 24 to 30 hours, and for a three-ton about 20 to 24. A great deal depends upon the experience of the man burning in, as a good operator will conserve every bit of heat and time, resulting in a shorter period of burning.

The hearth is now in such a condition that a bar thrust against it will ring, as if hit against a concrete wall. If desired a wash heat can now be made to thoroughly set the bottom. I recommend that this heat, if used, be a heat of grey iron made from steel scrap, as this character of a heat will always melt and run clean, and appears to leave the bottom in better condition than any other metal. As soon as this heat is tapped the bottom can be slightly patched if needed, but this is unnecessary if the first burning has been properly done. The walls, above the slag line, can be touched up with a good grade of dolomite, or any of the trade materials such as syndalogs, magdalogs, etc.

Great care should be taken of the hearth during operations. After each pour some time should be spent in cleaning out small holes in the hearth, and in keeping the slag line clean. Good alloy steels can never be made on a poor hearth, or in a hurry, and it pays to take plenty of time on this subject of repair. Great care should be exercised not to use too much patching material, as it will only come up in the slag on your next heat offering further problems.

The same applies to the nose or tapping spout. It should at all times be kept free of scuffs, slag accretions and holes. Magnesite mixed with a small amount of sodium silicate, and well rammed in and dried, offers an excellent material for a good clean spout which will usually last much longer than one built of brick.

Class of Scrap.

In the manufacture of any high grade steel a great

deal of the success obtained is due to the character of scrap used. While it is possible, of course, to make good steel from inferior scrap, it follows that every additional operation necessary through this practice greatly increases the conversion cost. Not only that point, but every time you boil the bath, with ore, to either lower the carbon, or to reduce phosphorous, you are placing oxide in direct contact with the metal, offering a splendid chance to have this objectional substance dissolved in the steel, some never to be eliminated. Such scrap as good punchings, ingot or mill butts, heavy plate or structural scrap offers an excellent raw material. Good heavy turnings are also good, if kept clean from oil, dirt, waste, etc. When it is considered that some of this steel in the ingot will cost over a hundred dollars a ton it certainly pays to add a few dollars to the initial scrap charge. Classes of scrap should be segregated mainly on their phosphorous contents, using such metal for each heat as will meet the specification without any unnecessary slagging off.

Raw Materials in General.

Lime should be of good quality, thoroughly burned, and as free of any objectional elements, such as sulphur, etc., as is possible. All car loads should be analyzed completely, and great attention paid to this point. Before using the lime should be crushed to a size of half-inch, or smaller, as time will be here saved when building a slag, which will more than pay for any shorter life of refractories, due to lime dust impinging on the roof or walls and causing a slagging action.

Fluorspar should contain over 85 per cent calcium fluoride, and be as low in silica as is commercially possible. This should also be crushed to about pea size.

Re-carbonizing materials should be low in ash and sulphur. If coal, or other unbaked carbonaceous material is used it should be as low in volatile matter as can be obtained consistent with cost. I have found several materials on the market which are exceptionally good for this purpose. Pitch or retort coke, flake graphite, clean anthracite coal, and similar carbons are all good to use, each filling its purpose well.

Charging Operations.

The charging of the furnace will follow the already common practice of placing the larger pieces on the hearth, and filling the cavities with smaller sized metal. It is often desirable, especially when the bottom is rather low, to charge some of the lime for the first slag onto the hearth before the scrap is charged. It is also often necessary to charge a small amount of coke, when it is desired to melt down under one slag only. Such alloys as nickel and tungsten when charged with the scrap, should be well down towards the bottom so that alloying will gradually proceed as melting progresses.

Plain Carbon Steels—These steels, especially those of from .30 to .55 per cent carbon, find wide use, being used in most forging work, both for light and heavy duty. While it is true that alloy steels are rapidly cutting in on their use there is still a great demand for a high grade metal of this character for such articles as forged gears, cams, crank-shafts, driving rods, axles, etc.

As a good example of this steel we can do no better than to take as an example a specification calling for: Tensile strength, minimum, 100,000 lbs. per sq. in.; El. limit, 65,000 lbs. per sq. in.; Elongation, over 15 per cent.

A steel which will easily meet this is one containing: Carbon, .40/.50 per cent; manganese, .45/.55 per cent. Other analyses standard with a phosphorous and sulphur under .04 per cent.

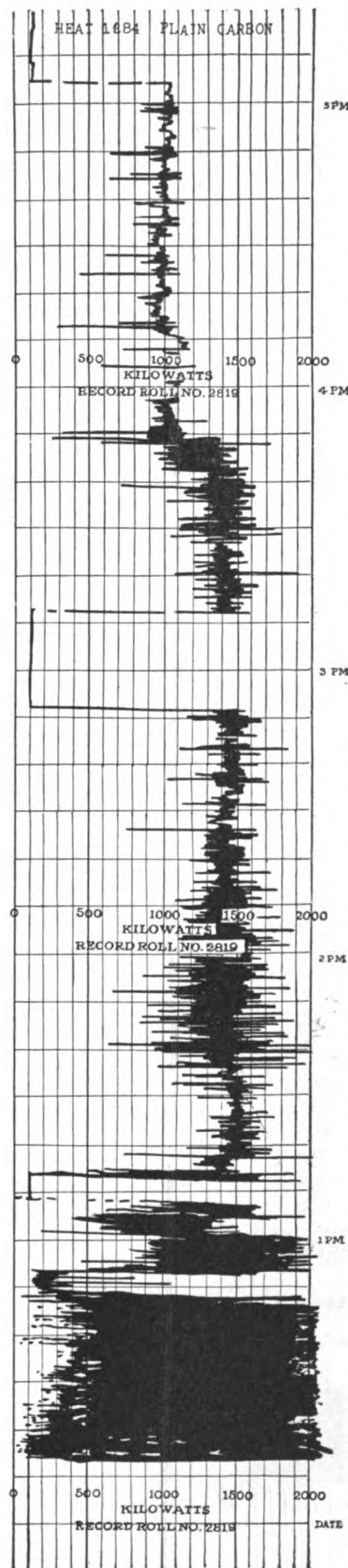
The furnace is charged with suitable scrap probably analyzing about carbon, .25 per cent; manganese, .50 per cent; silicon, .08 per cent; phosphorous, .04 per cent; and sulphur, .045 per cent, such as is commonly made in the basic open-hearth furnace for rolled work. The current is turned on and the doors closed and sealed. As soon as the electrodes have run down, and are in close proximity to the bottom, the doors are opened, the electrodes raised, one-half of the lime for the first slag thrown into the holes, the holes filled with scrap, and the melting again started. Care should always be taken in this manner to prevent the electrodes digging, and cutting the bottom. The heat will now melt down rather fast. When melting is nearly completed the doors should again be opened, the scrap on the walls shoved in, and the balance of the first slag added. In this instance the first slag will consist of 2 per cent of the charge, lime, and 10 per cent of the lime clear white sand. As soon as all is melted a test of the slag is taken. This should show a dead black, and should be of medium consistency. If too thick it can be slightly thinned with fluorspar—if too thin more lime can be added. When the metal is sufficiently hot the first preliminary test can be taken, poured into a chill, quenched and broken for fracture. This will show very low in carbon and will necessarily be low in manganese and silicon. We will assume this test to be at .08 per cent carbon, with all conditions favorable to slagging off. Shut the current off and hold in this condition for several minutes. If there is a slight boil in evidence a handful of fine ferro-silicon thrown in on the spot will quiet this. As soon as the slag has quieted, the furnace is slightly tipped and the slag drawn off. What will not run free must be raked out with hoe shaped rabbles, well slag covered. When the bath is fairly free a few shovels of fine lime are thrown on its surface, and what slag remains will quickly coagulate and can be removed. A slag of this character made from scrap which is slightly rusty, will remove at least .02 per cent of phosphorous, based upon a volume of $2\frac{1}{2}$ to 3 per cent of the charge.

Enough recarbonizer to raise the carbon to .35 per cent, and manganese figured at .30 per cent are now added to the bare metal, and the current turned on. This carbon will usually start a small boil, sometimes rather violent, and often the re-carbonizer must be added in small lots. In about 10 minutes or less the free carbon will all be absorbed, as denoted by the rapid

HEAT LOG OF PLAIN CARBON STEEL

Specifications:		Steel made:	
Carbon	.40/.45	Carbon	.43
Manganese	.45/.50	Manganese	.53
Silicon under	.12	Silicon	.09
Phosphorus and		Phos.	.038
Sulphur, less than	.045	Sulphur	.016
Charge:		Approximate analysis:	
Ingot croppings	8,000 lbs.	Carbon	.25
Boiler plate	6,000 lbs.	Manganese	.50
Heavy turnings	3,000 lbs.	Silicon	.05
		Phos.	.04
		Sul.	.04
Total	17,000 lbs.		

Material charged as follows: Turnings on the hearth, then the boiler plate, then ingot butts, with about 1,500 lbs. of the latter left to fill up holes as melting proceeds.



- 5:05—Metal poured.
- 4:50—Final metal test taken showing excellent conditions. Slag very heavy in carbide.
- 4:30—Analysis back from chemist at .35 per cent carbon and .40 per cent manganese. .10 per cent manganese added. .05 per cent carbon added directly under the electrodes and rabbled in. Silicon at .10 per cent added. Flame oily with heavy black smoke coming from furnace.
- 4:15—Slag strongly carbide. Ferro-silicon figured at .05 per cent added. Doors sealed. Flame brilliant, soot beginning to come out from around the cooling rings.
- 4:00—Slag test showing light brown, fluidity good, conditions strongly reducing. Metal test taken for chemist.
- 3:50—Slag well rabbled, given 25 lbs. fluorspar, and another dusting of coke.
- 3:15—Current again on. Second slag made up containing 300 lbs. lime, 100 lbs. fluorspar, and 50 lbs. ground coke. Added at intervals during the next 20 minutes. Then given a good dusting of ground coke.
- 2:50—Current off, slag raked from furnace. Three scoops of fine lime added, and balance of slag removed. Metal "dead." Manganese calculated to .25 per cent added together with anthracene coal, figured to .20 per cent available carbon.
- 2:40—Slag dead black, boil very low. Conditions good.
- 2:25—Charge all in, 50 lbs. lime and 50 lbs. fluorspar added, bath under a light boil. First preliminary test taken, showing carbon about .10. Slag oxidizing, heavy black, medium fluid.
- 2:15—Charge nearly melted, 200 lbs. lime and 50 lbs. ore added.
- 1:10—Holes again filled with balance of scrap on platform.
- 12:55—Current again on.
- 12:45—Electrodes down to hearth, current off and 100 lbs. lime added to holes, and the holes filled with scrap.
- 12:15—Current on.

drop of the flame emitting from the roof ports. One half of the second or finishing slag is now added consisting of 2 per cent of the charge lime; 20 per cent of the lime spar; several scoop shovels of powdered coke; well mixed together. The doors can now be closed, and

HEAT LOG PLAIN NICKEL STEEL

Specifications:

Carbon .30/.35
Nickel 3.25/3.75
Other elements standard

Steel made:

Carbon .31
Nickel 3.62
Silicon .12
Phos. .040
Sul. .026

Charge:

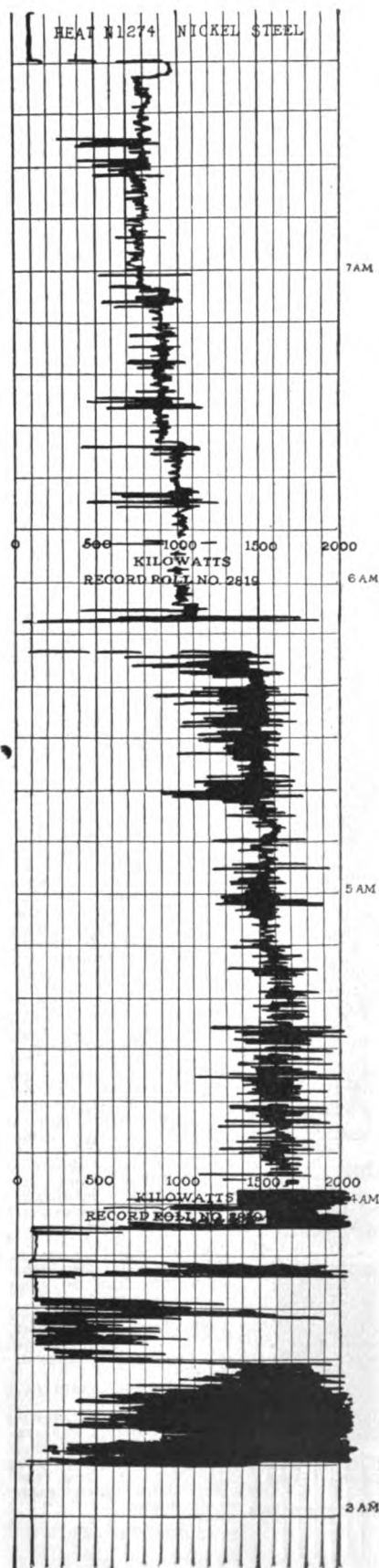
Nickel scrap 11,000 lbs.
Ingot butts 4,500

Total 15,500

Analysis of charge:

Carbon .30
Nickel 2.50

Sufficient pig nickel added on hearth to bring charge up to 3.50 per cent nickel, together with 100 lbs. burned lime.



7:35—Heat poured.

7:25—Final fracture test taken, .15 per cent lump silicon added.

7:00—Chemist reports carbon .30 nickel 3.55, and manganese .52. Furnace sealed and allowed to soak under carbide slag.

6:30—Slag rounding into shape rapidly, conditions excellent. Another dusting of coke, together with 50 lbs. fluorspar added in small portions to different sections of the bath.

6:15—Balance of second slag added and heavily coked. Metal test taken for chemist. Doors sealed.

5:55—Current shut off, and most of the first slag raked off. Ferro-manganese added, and second slag added.

5:00—Metal nearly melted. Slag gradually brought into proper condition during the next 40 minutes, by means of additions of spar and a small amount of sand.

3:10—Current on. From this time until nearly 4 o'clock scrap added to gether with small additions of lime, to bring total lime up to 2 per cent of the charge.

luted on one side (if in a three-door furnace). In about 10 minutes the balance of this slag can be added, directly under the electrodes, and the slag given a good dusting of powdered coke. During this time the skimming gate has been set and luted, and is now being dried with an oil or gas flame; the ladle is also under the fire.

The flame coming from the roof ports will gradually turn from a sharp reddish to a soft luminous one, denoting that reducing conditions are now materializing. The slag can now be examined, both for color, texture and fluidity. This will gradually change from a black or brown, to a lighter brown, through a grey, until the final white carbide slag is obtained. It may be necessary during this period to add either lime or spar to bring this condition about. As soon as the slag powders in the air, and gives off the familiar acetylene odor when quenched, perfect reducing conditions are obtained. The bath is given another good dusting of coke, and another metal test taken. This test goes to the chemist for carbon and manganese, but is also judged at the furnace by fracture. The flame will now gradually die down and either soot or volatilized silicon may be emitted from the furnace. The heat is now under perfect conditions, the sulphur being rapidly eliminated. Ferro-silicon calculated to .05 per cent can now be added to cleanse the steel of any small adhering oxide, and to promote progress of solidity. When the analysis returns the final additions can be made to the furnace, and the final test taken. As soon as all conditions are correct the heat can be poured.

A moist sack is quickly thrust in the nose and the furnace rapidly titled. The sack will hold back the slag for just long enough to allow the metal to rise up over the skim gate, the slag flowing into the ladle on top of the metal. The pouring practice will be handled later.

Chromium Steels—Steels with chromium contents running from .50 per cent up to 2.00 per cent with carbons as specified.

These steels are handled in exactly the same manner as in the proceeding outline for carbon steels, with the addition of chromium added at least 30 minutes before the pour. When the larger additions are made it is good practice to add the ferro-chrome on the sill just inside the door for several minutes before shoving into the bath, as a means of slightly pre-heating. It will also be necessary to slightly change the final carbon additions to compensate for that contained in the ferro-alloy. Chromium is very easily oxidized, and for this reason more care must be taken of the slag than with carbon steels. I advocate adding 10 per cent more chrome than needed to compensate for the slight losses of this metal which will invariably occur, even under the best of conditions.

The Remelting of Chrome Steel Scrap.

In order to conserve this alloy it is manifestly impossible to slag off or your purpose would be completely defeated. The practice must therefore be slightly changed, and this steel will be described as made under the one slag process. The scrap is charged as before, but in addition coke figured to 10 points plus the specification desired is added. If the order called for .50 per cent carbon you would add coke at .60—if at 1.00 per cent you would add coke at 1.10 per cent. This is to provide the necessary carbon to overcome the rust on the scrap and to cause the heat to melt at a point slightly under your desired figure, calculating to pick up 10 points of carbon during the finishing operation. This figure will naturally change according to the character of the scrap the amount of rust, etc. Rusty scrap will generally lose 20 points on the melt down, while rattled scrap will probably lose less than .05 per cent of carbon. One half the lime is added but no fluorspar or sand, and the heat is melted as under the two slag process.

As soon as completely melted the balance of the slag, mixed with ground coke and fluorspar is added, the bath given a good dusting of ground coke, and the doors tightly sealed. The better seal here obtained, the quicker will reducing conditions ensue. The slag at this period may range from a black to a green grey, depending upon how oxidizing conditions were during the melting. According to the color you will add your ground coke, the darker the color the more you will need. The slag will now seem to hold, but will finally begin to turn lighter in color as reduction proceeds. This period requires expert manipulation in order that the slag may be cleared as quickly as possible without raising the carbon content over that desired. The furnace should be kept closed as much as possible, and soon the change in the flame will show progress. It is possible for a skilled melter to know exactly what is progressing inside his furnace merely by the appearance of this flame, and the sound of his arc. When the slag is in carbide form the final test of metal for the chemist is taken, and final additions are made upon receipt of his report. Within 20 or 30 minutes of the final chrome addition the heat should be poured. The time necessary to hold under the carbide slag before making the final additions will all depend upon the steel desired, the percentage of carbon, etc., but it is well to understand that it is far better to hold too long than to pour too soon.

Nickel Steels Up to Five Per Cent Nickel.

This class of metal can be handled in the same manner as under carbon steels. The nickel can be added with the charge in the form of pig nickel, and the course of the heat pursued. Nickel is extremely hard to lose by oxidation, and requires no special methods of melting. Fractures containing percentages of nickel over 3 per cent show a difference from those of similar carbon steels, and the chemist must be relied upon to a greater degree. Care should be taken with these steels against over heating as this tends to cause over oxidizing. Nickel steel in the wild condition offers one of the most difficult problems the melter has to handle. The best method of coping with such a situation is by constant working of the metal, together with additions of silicon. This is added in lump form, moistened so it will break through the slag into the metal. When the metal shows sound an analysis will have to be made for silicon, and if too high ore will

HEAT LOG CHROME NICKEL STEEL

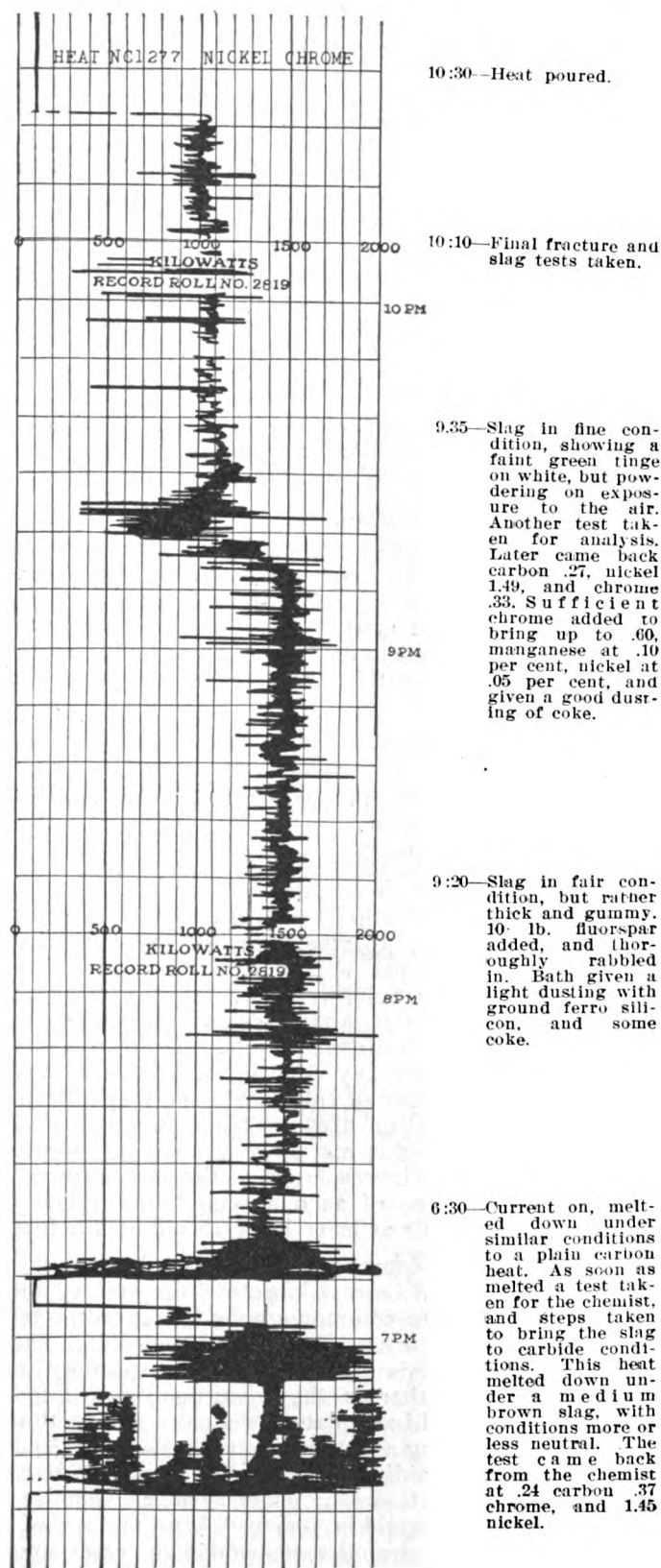
Specifications:
Carbon .25/.30
Nickel 1.35/1.55
Chrome .50/.60

Chrome .52
Steel made:
Carbon .30
Nickel 1.51

Charge:

Chrome nickel scrap 14,000 lbs.; analyzing carbon, .24; nickel, 1.50; chromium, .55.

200 lb. lime charged on the hearth, together with ground coke figured at .40 per cent.



have to be added, and the heat slagged. Silicon is thus easily reduced, but the steel cannot be classed as real first quality metal. I have found calcium-silicide to be an excellent de-oxidizer under such circumstances as the affinity of calcium for oxygen is so much greater than the nickel that the over oxidized condition is gradually eliminated.

Nickel Chromium Steels.

Handled by a combination of the above methods, depending upon the alloy contents in the raw scrap.

Molybdenum Steels.

This class of alloy steels are best made by the two slag methods of manufacture. After slagging off, and before building the second slag, the alloy can be added in the form of calcium molybdate, the final slag added, and the heat finished under carbide conditions. If ferro-molybdenum is used it should be added to the furnace in a similar manner to ferro-chrome, after the white slag appears. When handling this metal in combination with such alloys as nickel and chrome they will be added as for their respective classes.

Steels With Vanadium.

The heat is finished and the vanadium added not over 10 or 12 minutes before the pour, giving it just sufficient time to thoroughly diffuse.

Pouring and Ingot Practice.

When using a skim gate on the furnace there is little chance for slag inclusions to appear in the metal. There are, however, always chances for slag to become trapped in the metal stream, small particles of ladle patching, etc., to become contaminated with the steel. As a means of eliminating these troubles I advocate several remedies:

1. Pouring superheated metal and holding in the ladle.
2. Adding a small amount of ground fluorspar to the ladle during the pour.
3. The use of ferro-titanium in the ground form in the ladle.

Superheated metal allows the maximum amount of any foreign inclusion to rise, together with any entrapped gas. Fluorspar will increase the fluidity of any non-metallic particles it encounters, as will the titanium. Titanium also eliminates any nitrogen present by its ability to form the nitride. Aside from the above I do not, under any conditions, believe in any ladle additions whether of coke, manganese or silicon. Aluminum is also eliminated, because in good steel there is no need of this metal, its use giving rise to added inclusions and increasing the shrinkage or "pipe." The metal should be of such a temperature that it can stand in the ladle at least 10 or 15 minutes before pouring the first ingot.

All ingots should be cast large end up, and a "hot top" used. This is so common among high grade steel makers that further discussion would be needless. The use of fluted ingots is strongly favored especially in the larger sizes, either in the square or multi-sided shapes. A hollowed base plate gives more satisfaction than a flat one, giving a rounded point to the lower end of the ingot, and aiding in the elimination of base cracks, and cold shuts on the lower surfaces. The interior of the molds should be very well kept, and a wash is favored of either graphite suspended in water and applied to the hot mold, or of lampblack in linseed oil.

A slightly higher cost of mold upkeep will always pay for itself in better ingots, with less scrap. The life of ingot molds can be prolonged by giving them a thorough anneal before the primary heat. Any small scabs can often be welded and ground, often resulting in many heats from a mold which normally was due for the scrap heat.

Top pouring of ingot molds is favored over the method of plate pouring for the reason that invariably runner brick will cut and peel, the silica inclusions remaining in the ingot. Molds should be "cold poured" the nozzle opened just far enough for the steel to rise with a "creamy top." Under no conditions should a stop occur during the pouring of an ingot, for a seam is bound to result, and while it may only be on the surface it often crops up in the finished forging after much expense has been spent on its fabrication. There

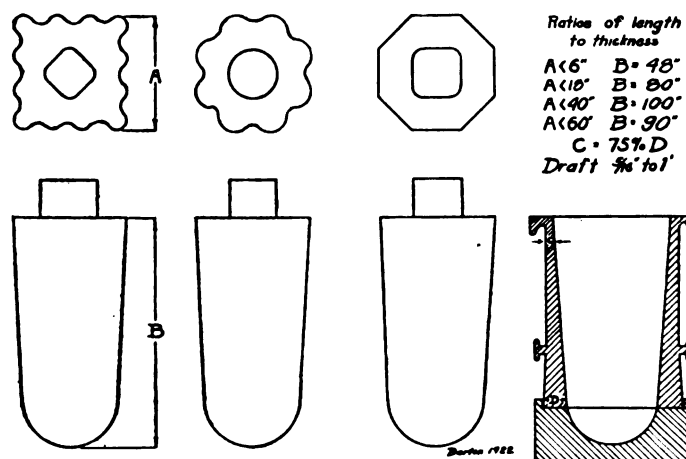


Fig. 6—Sketches of approved ingot and mold design used in top pouring, with hot tops.

are certain cases, as in a large ingot, where bottom pouring must be resorted to. For such class of work it is desirable to fill the mold about one-third to one-half full, and then finish by top pouring. The hot top is then set and the ingot filled. The best hot tops are those made from well burned bricks of good material, sand molded ones offering a chance for inclusions to creep into the metal.

Ingots should be stripped as soon as possible and allowed to stand end up until perfectly solid, when they may be placed in the soaking pits. This condition is obtained when the corners begin to show slightly black. Fig. 6 shows some sketches of ingot and mold design which have proven acceptable for the above described work.

RAILWAY DEPARTMENT EMPLOYEE TRANSFERRED

E. D. Lynch, Railway Department, Westinghouse Electric & Manufacturing Company has recently been transferred to the New Haven office of that company. Mr. Lynch has been engaged in railway activities since graduating from the Baltimore Polytechnic Institute. He was engaged in assisting in the negotiation work of the Railway Department, but at a reorganization of the Railway Department, he was appointed Office Manager of the department. At New Haven Mr. Lynch will fill the vacancy made by Mr. J. P. Alexander's removal to the Boston office of the Westinghouse company.

By-Product Coke Oven Operation "10" Pushing Series

Uniformity of Products Depends upon Correct Series—Close Approach to Theoretical Correctness—Other Important Factors—Diagrammatical Demonstration.

By A. COE

PROBABLY no one operating feature of a by-product coke plant has been more thought of, discussed and theorized upon than the pushing series. It receives consideration as the time approaches for starting up the new plant and in existing plants, as its importance is recognized and every effort is made to get the best possible results. It is now generally conceded that "uniformity" of operation of a coke plant, particularly the batteries, gives best results as to the life of the apparatus and as to quality and yield of coke; raw, surplus and fuel gas; tar and other by-products. "Uniformity" of operation should be uniformly good operation. However, some plants are not capable of uniform operation, not necessarily because of faulty design or construction, but from such factors as non-uniform coal supply, etc. It is because of this desire for uniformity that the pushing series has been given so much consideration. Without doubt the best "10" pushing series has been in use for many years (we discuss the "G"

series later); it is generally conceded that the only practicable pushing series is a "10" series; as is evidenced by the fact that probably without exception, every by-product coke plant uses a "10" pushing series.

Some have thought that the importance of the pushing series warranted using some other than the "10" series and have proposed an "11" or other series, upon the assumption that the ideal pushing series would be one in which the age of the first oven on

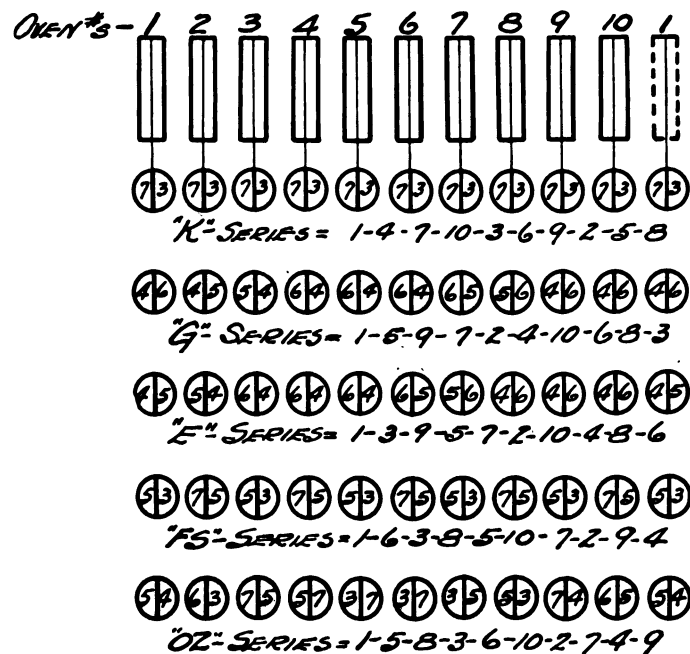


FIG. 1—PUSHING SERIES—The above diagram shows, for various pushing series, the age, in series, of the first oven to the right and the first oven to the left when any oven is pushed. For instance when oven No. 7 of the "G" series is pushed the first oven to the right (No. 8) is 5 series old and the first oven to the left (No. 6) is 6 series old. Series difference is the hours difference when the gross coking time is 10 hours, or in direct ratio for any other coking time—for instance, "G" series, if the coking time is 20 hours: When oven No. 7 is pushed, oven No. 8 is $20 \times 5/10 = 10$ hours old and oven No. 6 is $20 \times 6/10 = 12$ hours old.

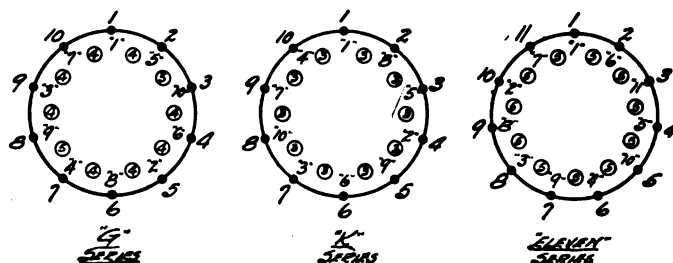


FIG. 2—PUSHING SERIES—Oven numbers outside of circle. Sequence numbers inside of circle, in quotation marks. Minimum difference in series in rings, inside of circle. To obtain the "pushing series," after having established the order of the "sequence numbers" by means of the "minimum difference in series": First, write the "sequence numbers," in numerical order: Sequence numbers = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10: "G" Pushing Series = 1, 5, 9, 7, 2, etc. Second, write under the sequence numbers the oven numbers opposite them (on outside of circle). To obtain the number of "series" difference between any two ovens, proceed as follows: "G" pushing series = $\frac{0, 1, 2, 3, 4 \text{ (5 forward)}}{1, 5, 9, 7, 2, 4, 10, 6, 8, 3, 1.}$

0, 1, 2, 3, 4, 5, 6 (6 reverse series between Ovens No. 2 and No. 1). New series may be obtained from any series by revolving the (oven) numbers outside of circle around the numbers inside of circle: Revolving "G" Series one number counter-clockwise we obtain: 1, 7, 9, 4, 2, 6, 10, 8, 3, 5. (See also "8" of the text.)

each side of the one pushed would be exactly one-half the gross coking time. It would seem that this assumption can be proper only if exactly one-half the Btu. are required and have been absorbed by the coal charge when one-half the coking time has elapsed, which seems unlikely; or if there is an exact heat balance as between each exactly one-half the gross coking time. It seems logical that either more or less than one-half of the Btu. have been absorbed by the charge when one-half the coking time has elapsed, rather than exactly one-half have been used, particularly when allowance is made for the actual (net) coking time being less than the gross coking time due to time between

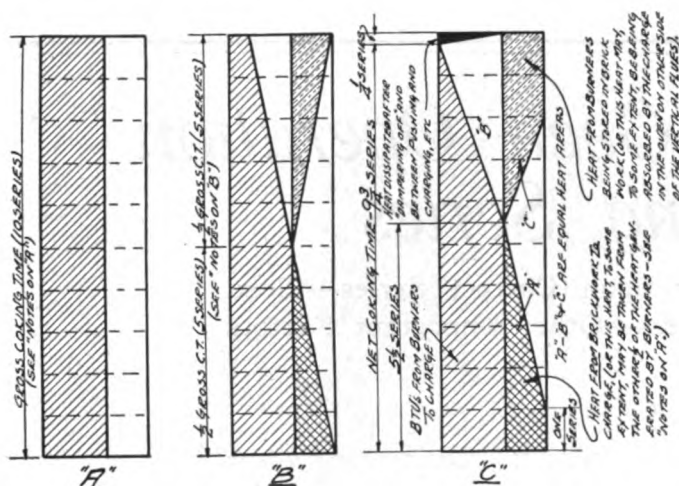


Fig. 3—In the following only the heat absorbed by the charge is considered. The heat in the stack gases and radiated to the atmosphere by the battery as a whole are not included—the heat to the stack gases and atmosphere are practically uniform, except for atmospheric changes and conditions. Notes on "A"—This diagram shows the heat uniformly generated, in other words the heat (Btu.) uniformly supplied, throughout the coking period, for the oven on one side of the vertical flues. It shows only one-half the heat generated or Btu. supplied, the other one-half going to the oven on the opposite side of vertical flues. Notes on "B"—This diagram shows the distribution of the heat supplied and shown by "A," as it is commonly considered to be distributed, that is an exact heat balance as between each exactly one-half the gross coking time together with no allowance being made for conditions between "dampering-off" and pushing and between pushing and charging (the notations to "C" apply descriptively to "B"). Notes on "C"—This diagram is submitted as showing more nearly actual conditions—see Notes in "B." It is fully explained by notations at the diagram.

"dampering off" and pushing, and between pushing and charging, etc. It is a reasonable assumption that more than one-half the Btu. are required for the first one-half of the coking period considering that the charge has to be heated from atmospheric temperature, water content heated to about 212 deg. F. and converted into vapor; this vapor raised to a higher temperature and probably the greater percentage of the tar distilled off in the early part of the coking period.

An attempt has been made in the following discussion and by means of the diagrams to show that with only our present knowledge of heat distribution and the coking operation a change from a "10" to an "11" or other series, is not warranted and that the "G," a "10" series, is better than other "10" series and the best obtainable. To do this, it has been necessary to make what are considered reasonable assumptions as to heat distribution, but without any actual data, as shown by Fig. 3 C and by Fig. 5 curves might have been plotted instead of straight lines, which would perhaps make a better appearance. Straight lines were used to make the work easier. Granting that the assumptions made are reasonable, it will be seen that there would be very little practical difference in operating results for example, as between the "G," a "10" series, and the "11" series.

In practice, with the best "10" pushing series obtainable (the "G" series), probably one oven is wholly or partially very slightly more coked and another very slightly less coked, or a charge may be slightly more coked from one side than the other but in this case their variations would be small. In the case of other than the best and depending upon the particular pushing series it would seem as though there must be over-

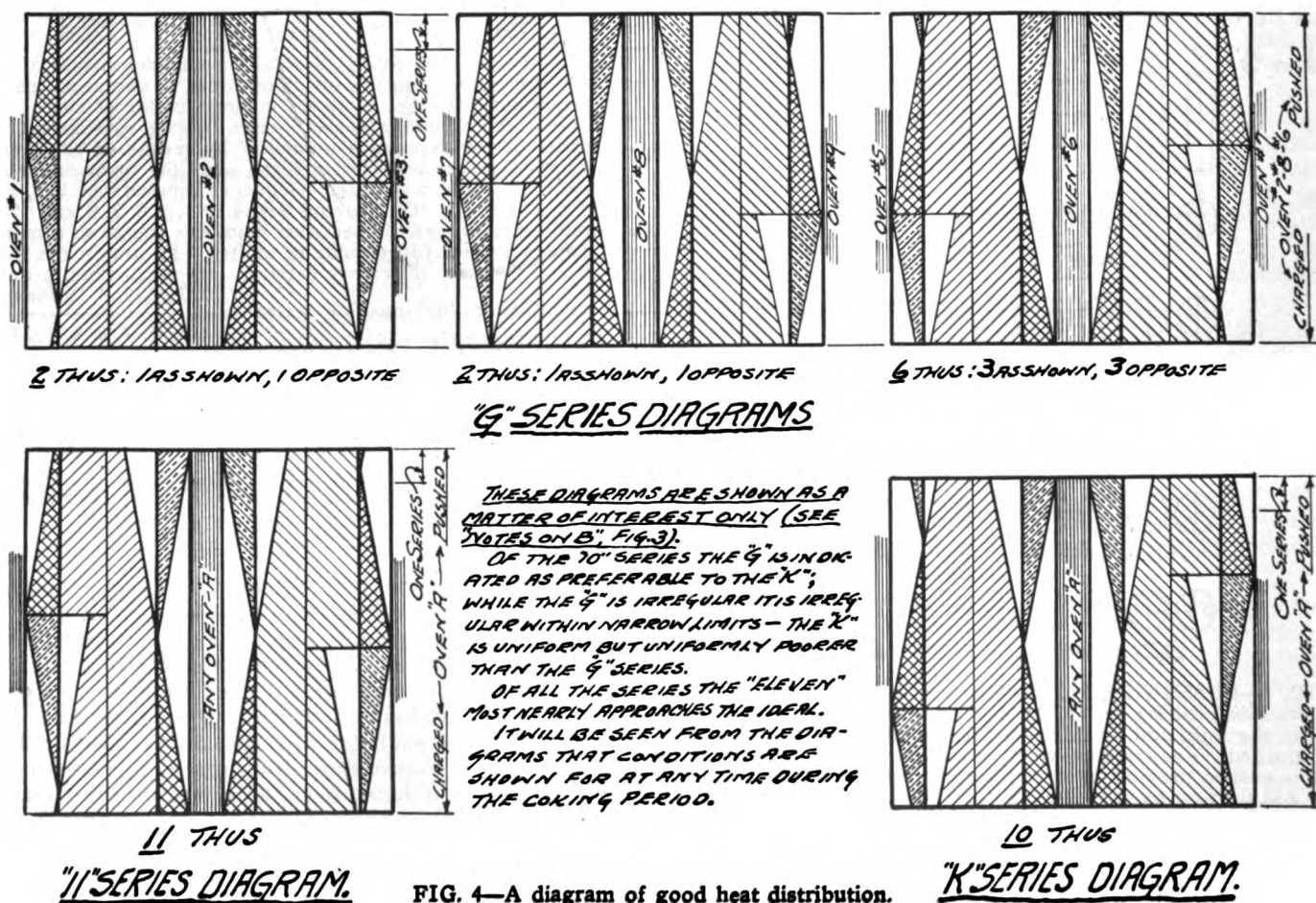


FIG. 4—A diagram of good heat distribution.

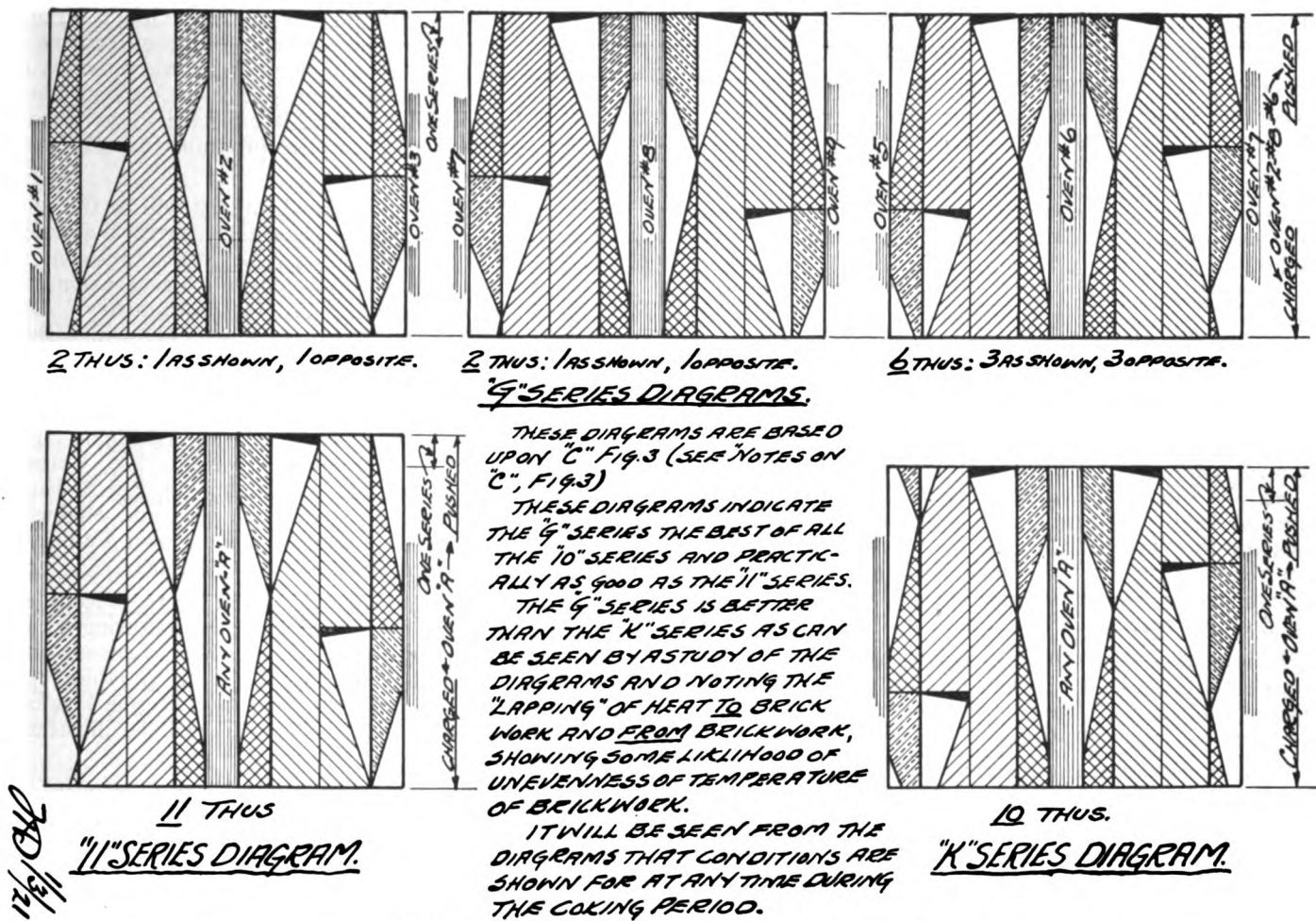


FIG. 5—Another example of good heat distribution.

coking and under-coking of the charge and unevenness of temperature of the oven brick-work.

With the best "10" pushing series obtainable (or even with the so-called "ideal" pushing series, granting such a possibility) together with a knowledge of theoretically correct heat distribution it would probably be impossible to obtain an absolutely uniform supply of Btu. to the individual vertical flues of any oven or to the individual oven of any battery and so forth. If anything like proper heat regulation exists, as to the individual flues or ovens, the difference between the results obtained and absolute perfection are very small indeed.

There are many other factors of more or less importance entering into the uniform heating of the oven charges as a whole, other than the pushing series and the heat "regulation." Of these many factors may be mentioned the "radiation" from the battery as a whole, the total Btu. required for coking the charge depending, to some extent upon atmospheric temperature with or without rain, snow, wind, sunshine, etc. Again the Btu. required to be supplied to successive charges for any particular oven depend somewhat upon the temperature of the charge, its moisture content and the "weight" of the charge (assuming constant volume). The total weight charged per oven varying with the moisture content, percentage of fines to coarse in coal only crushed, etc.

Referring to Fig. 1 the "K" series may be described as "uniform"; the "G" and "E" series as somewhat irregular, but giving identically the same operating re-

sults. The "FS" series as a combination uniform—irregular; and the "OZ" series as entirely irregular. We should say that the "FS" and "OZ2" series would give very uneven temperature of oven brickwork and un-uniform coking of the charge throughout the coking period with its consequent ill effects on coke, by-products, etc., and oven brick-work.

The series most used are the "G" series, or those that may be derived from it, and the "K" series. Other "10" series commonly used are not to be compared to the "G" and "K" series. The "E" series may be obtained from the "G" series (see Fig. 2) by revolving the "minimum difference in series" one space counter-clock-wise and thus obtain the new arrangement of "sequence numbers" 1, 6, 2, 8, 4, 10, 5, 9, 3, 7. The "E" series is obtained as previously explained from the "G" series Fig. 2. An "11" series derived as explained in Fig. 2 is, 10, 8, 6, 4, 2, 11, 9, 7, 5, 3, 1.

Figs. 1 and 2 indicate briefly the method of deriving and portraying a pushing series without the aid of mathematics. They were evolved by the writer in 1915 to indicate which of several "10" pushing series is the best. The writer demonstrated at that time that the "G" series was preferable as shown by Fig. 1. Fig. 2 only briefly describes the method of deriving a pushing series, since it is thought that the reader knowing that the best "10" series already exists (the "G" series), and will not care to derive other series. If he should, it is considered that enough explanation is given to serve the purpose. Figs. 3, 4 and 5 elaborate upon Figs. 1 and 2 and further demonstrate the "G" the best of the

"10" series and as good as can be obtained, being in the writer's opinion, practically as good as the "11" series

The problem of choosing a pushing series is not to obtain the same heat treatment for all ovens (as is given by the "K" and "11" series) unless this is obtained together with other advantages. Nor is it a problem of the best "average" heating of all the ovens, because in this case some ovens might be very good and some very bad and still have the best average. The problem is to choose a compromise as between uniformity and irregularity, such as is given by the "G" series as shown by Figs. 1 to 5, inclusive. Consideration should be given to "evenness" of temperature of the oven brick-work throughout the coking period. The temperature should not be higher at one time of the period and lower at another, as this condition, at least if excessive, shortens the life of the oven brick-work. However, unevenness of temperature probably cannot be entirely eliminated with any series. From the diagrams of Figs. 3, 4 and 5, we conclude that the "G" series and the "11" series would give a more nearly uniform temperature of the oven brick-work and more uniform coking of the charge throughout the period than the "K" series.

By means of diagrams Figs. 3, 4 and 5 the writer believes he has made a consideration of the pushing series much easier. These diagrams were decided upon only after the consideration of many others.

This discussion of the pushing series has been made as brief as possible, since the proposition involves the whole theory of oven-heating and the distillation process and unless considered in the simplest way possible, might result in one becoming involved in a maze of theoretical and practical considerations. For instance, it is conceivable that the charging of any particular oven may, even if only for a short period of time, decrease the flow of heat slightly to the contents of the chamber two ovens away, depending upon the pushing series used. Or there might be a slight flow of heat from the contents of the next oven to the oven just charged depending upon its age, etc. Increase in temperature of waste gas from one oven would affect all ovens, however slightly any leakage through the oven walls either way would affect that oven and all ovens. Such conditions may be neglected in considering the pushing series.

To obtain advantages over the "10" series would require a quite large series. Such a series would make it necessary to have all the ovens in several batteries in one row worked as one battery and would be impracticable for many reasons such as confusing results from the pushing series itself, great movement of oven machinery, involving much loss of time, etc.

Mention should be made of a very fine mathematical treatment of the pushing series with particular stress upon the advantages claimed for the "11" series by Mr. William B. Marquard, U. S. Patent Number 1,323,711. This paper treats very exhaustively of the pushing series and draws comparisons between the "10" and "11" and other series.

NEW YORK MEETING OF A. S. M. E.

More than 2,000 engineers representing practically the entire range of American industry will attend the annual meeting of the American Society of Mechanical Engineers, to be held in the Engineering Societies Building, New York City, December 4 to 7. This

meeting, planned as the biggest in the society's history, will attract leaders in engineering, education, economics and numerous fields of technology from every section of the country. Fully 10 per cent of the society's membership, now approaching 20,000, is expected to participate in the proceedings, the complete program for which has just been announced.

A central feature of national interest will be the joint session Wednesday evening, December 6, with the American Economic Association. E. M. Herr, president of the Westinghouse Electric & Manufacturing Company, will speak on "The Human Problem in Industry." Dr. Wesley C. Mitchell of Columbia University will deliver an address on "Making Money and Making Goods." Prof. H. R. Seager of Columbia, president of the American Economic Association, will lead the discussion, in which President David Friday of the Michigan Agricultural College, Dean Dexter S. Kimball of Cornell, president of the American Society of Mechanical Engineers, and other well known economists and engineers will share. This meeting will mark the growing union of effort between the economist and the engineer.

The ordnance division, of which army officers are among the leaders, has arranged for the following speakers: Major J. B. Rose, U. S. A., Fort Leavenworth, Kan., "Machining and Lapping Very Deep Holes"; R. A. Vail, Detroit, "Manufacture of Gun Recoil Mechanism." Recent ordnance developments will be illustrated by motion pictures.

At the management session, ten years of progress in management will be outlined by L. P. Alford of New York. Wallace Clark of New York will deal with "The Installation of Management Methods," and W. L. Wotherspoon of New York will discuss "Refining and Rolling Mill for Monel Metal." Chester B. Lord of Richmond, Ind., will deal with "A Visual Method of Control." Committees on Measurement of Managerial Ability, Standardization of Terminology and Standardization of Graphics will present reports to their chairmen, A. L. De Leeuw of New York, F. E. Town of New York and John J. Swan of New York.

On the opening day of the meeting there will be a session on "Training for the Industries," at which these reports will be submitted: Extension and Correspondence Schools, by James A. Moyer, Boston; Schools for Apprentices and Shop Training, by R. L. Sackett, dean of engineering in Pennsylvania State College; Industrial Education as Represented in Schools, C. R. Richards of Cooper Union.

At the safety engineering session on December 7, M. G. Lloyd, chief of the Safety Section of the United States Bureau of Standards, will speak on "Safety Codes," M. C. Goodspeed of Erie, Pa., leading the discussion. Other speakers at this session will include A. D. Risteen of Hartford, Conn., and G. E. Sanford of Detroit.

Speakers at the power session will include G. A. Crook and W. S. Morrison of New York, Linn Helander of East Pittsburgh, Pa.; Paul W. Thompson, S. S. Sanford and Sabin Crocker of Detroit, and B. N. Broido of New York.

Addresses at the fuels session will be made by Thomas A. Marsh of Chicago, G. I. Bouton of Detroit, H. F. Lawrence of Philadelphia and A. H. Blackburn of Worcester, Mass. Alfred Cotton and John Hunter of St. Louis will speak on "Ash Handling" at the Materials Handling session.

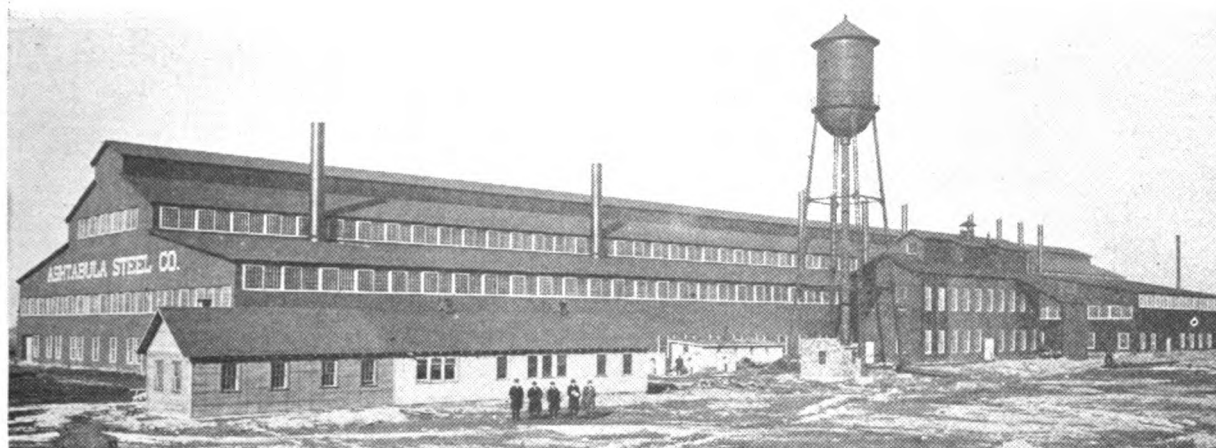


Fig. 1—View of the recently completed sheet steel plant of the Ashtabula Steel Company.

Sheet Steel Plant in Ashtabula Completed

Ideal Location Makes for Favorable Buying and Selling—Pulverized Coal Firing Used Throughout—Rolling, Annealing and Galvanizing Discussed.

By FRED J. CROLIUS

THE same public spirit which manifested itself in the beautiful Ashtabula Hotel—a community sense of unselfish co-operation, a compounding of individual effort through a Chamber of Commerce which actually functions, not annually but hourly—this same combination of constructive forces built the Ashtabula Steel Company, and these same forces will expand it to its logical boundries, and will surround it with the creature comforts of a progressive city. Almost the entire financing aggregating nearly \$1,500,000 was done locally by the citizens of Ashtabula city and county.

A better site for this particular character of development would be difficult to select. Situated about two miles east of Ashtabula, almost within sight and sound of the mammoth ore and coal transfer docks of Ashtabula Harbor, long famous as one of the very fine Lake Ports, where more ore was handled in 1920 than in any other port in the world, its transportation facilities are unrivaled. The New York Central R. R. adjoins the plant property with a track frontage of 3,500 feet. The property comprises some 48 acres of level ground. Close transfer to the Pennsylvania R. R. and the Nickel Plate furnishes railroad competition from the best raw material supply points and ready shipment facilities to the cream of sheet steel markets. These three roads offer direct routings and rapid deliveries to the Cleveland, Pittsburgh, Detroit and Chicago districts.

Principle raw material supplies—necessary in the operation of this type of mill—coal, sheet bars, spelter,

*Engineering Editor.

are immediately available under competitive conditions, and in emergencies can be secured over night. Labor, both skilled and unskilled, can be found here if anywhere, as living conditions, nearness to farms and lake operations are unusually favorable.

General Plant Layout.

The plant itself leaves little to be desired—it is the very last word in design and construction for a mill—operation.

The aim was to roll and finish sheets—plain, black galvanized, annealed, corrugated. There was no other confusing alternative.

The entire design of the plant and structure was subordinated to that one aim; the result is “a sheet mill second to none.”

The general character of the plant scheme may be said to revolve about the fuel development. Puverized coal was the fuel selected, and the engineering advantages inherent in this flexible form of heat units have shown a strong influence on all subsequent operations. Where hand firing or stokers require the transport and storage of coal scattered promiscuously about a mill, where producers carry with their operation a certain amount of dampness, ashes and clinkers—this plant has none. It is as clean and dry as a natural gas fired plant; even the boiler house, which instead of being an undesirable eyesore, is actually a spot of interest, a desirable part of the plant power-house.

A description of the plant layout and mill may well start with a discussion of the power-house and fuel minimum of labor and superintendence.

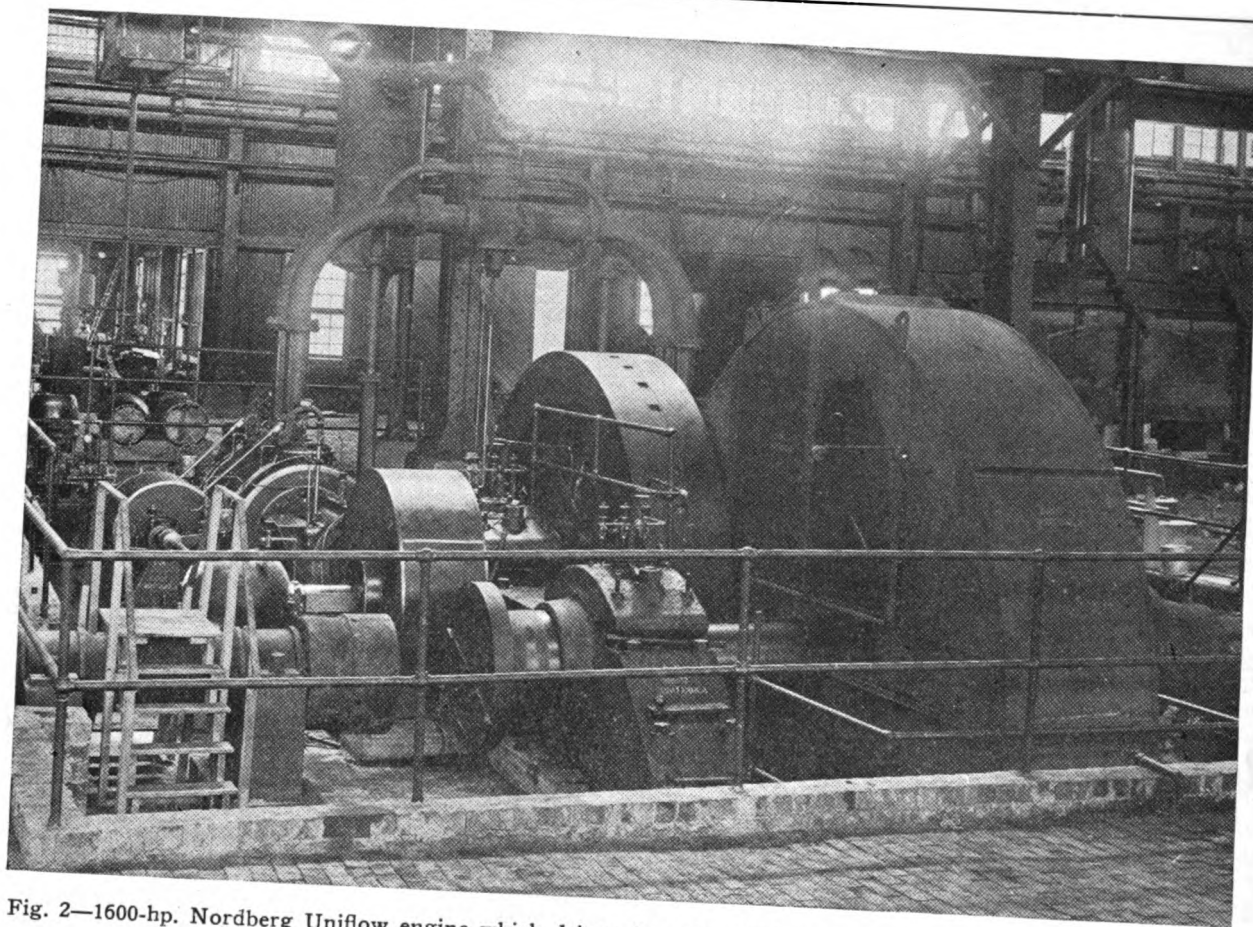


Fig. 2—1600-hp. Nordberg Uniflow engine which drives the rolls. This engine revolves at a speed of 150 rpm. and is geared through Falk gears to 30 rpm., the normal roll speed.

Power House.

Reference to the general plan, Fig. 3, will show these departments separately housed in adequate buildings, contiguously located at most advantageous points for shortest steam lines and powdered coal distributing lines. Every feature that contributes to safety has been complied with.

Two 450 hp. Union Iron Works horizontal water-tube boilers, with Foster superheaters, operating at various over-ratings, generate steam at 180 lbs. pressure and 100 deg. F. superheat. Adequate combustion chambers allow a continuous operation, non-clogging, even on the poorest grades of coal over monthly periods. Excellent cleaning facilities have been provided so that a minimum of labor maintains uniform results.

A single fan-tail burner, horizontally placed in the front wall of the extension furnace of each boiler insures excellent combustion of the finely powdered coal.

The power plant engine is a 750-hp Nordberg Uniflow with 22 in. by 32 in. cylinder operating at 150 rpm. direct connected to a 350-kw a.c. General Electric generator and a 175-kw. Crocker Wheeler d.c. generator mounted on the same shaft. Off the same shaft, belt driven at 750 rpm. is operated one 450-kva., d.c. General Electric generator; 3 phase, 60 cycle, 240 v. is used in alternating current generation, while 250 volts are used in d.c. generation. Also one 60-kw. Crocker Wheeler-Buffalo engine direct connected unit is used when starting.

Steam driven auxiliaries consist of; two 10 in. by 6

in. by 10 in. Worthington duplex boiler feeder governed by "S-C" pump governors; (S. C. feed water regulators control and boiler feed regulation).

One 40 hp., 1150 rpm. DeLaval turbine is used to drive direct on the same shaft; a 1600-gal. centrifugal pump to the Ingersoll-Rand condenser and a 2000 gal. centrifugal pump to the cooling pond; both operating against a 35 ft. head. The cooling pond is equipped with 4 stands of 30 spray nozzles each. Approximately 40,000 lbs. of water per hour are evaporated, condensed, cooled and re-used. An 8 in. by 8 in., 22 in. by 8 in. Ingersoll-Rand Vacuum engine functions with the condenser.

Circulating and conveying air for coal to the boilers is furnished by one 40 hp. DeLaval Turbine direct connected to a fan unit operating at 3400 rpm.

Motor driven auxiliaries consist of—two 75 hp. motors driving the two Fuller-Lehigh pumps; two 25 hp. motors driving the two Fuller Kimyon pumps; two 25 hp. motors driving the screws from boiler fuel storage bins; one 20 hp. Allis-Chalmers emergency air circulating pump; one 15 hp. on Nat. Brake & Elec. Company air compressor, delivering at 1155 rpm, 90 lbs. air for Fuller Kimyon distributing system.

Pulverizing Equipment.

Two Standard 42-in. Fuller-Lehigh coal pulverizers of the fan discharge type, combined capacity 10 tons per hour discharging directly through individual 6-in. Fuller Kimyon pumps into the 5-ton tanks or weigh

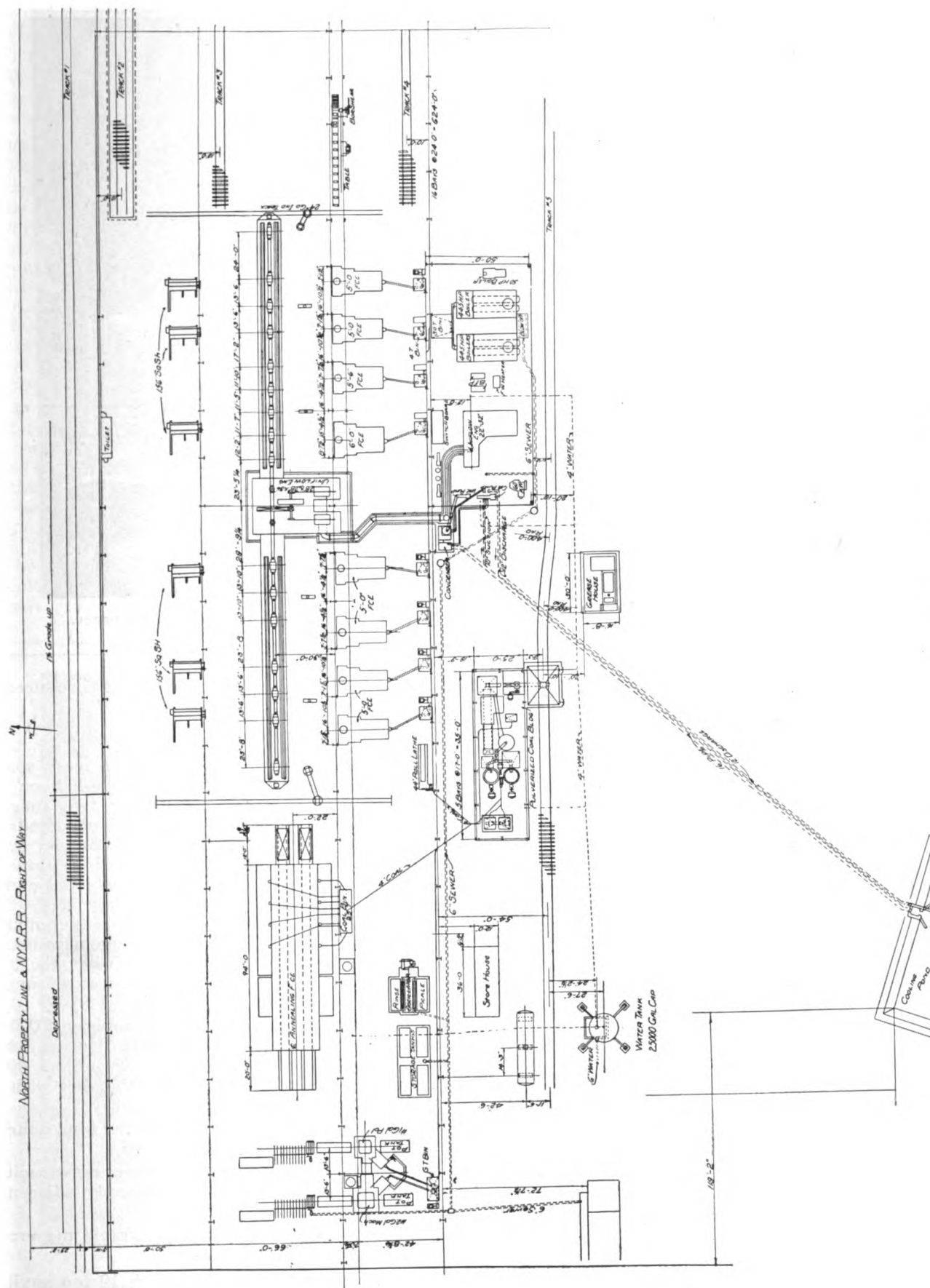


Fig. 3—Plan view of the new sheet steel plant at Ashtabula



Fig. 4—Rear view of heating furnaces showing hoppers for powdered coal and feed lines to furnaces.

bins meet all fuel requirements both for steam power, for heating and annealing furnaces, and for galvanizing pots. No cyclone separators are used.

All coal unloading for the entire plant operation is concentrated at one point. Broad gauge cars dump into the coal elevator pit. From it, it is hoisted to overhead storage bins of ample capacity. From the Jeffrey single roll crusher and pan conveyors the coal goes to a magnetic separator, thence to rotary indirect pulverized coal-fired Fuller-Lehigh drier where moisture is extracted so that one percent or less remains, thence to pulverizers which reduce to approximately 85 per cent through 250 mesh, all through 100 mesh. The cost of this complete pulverizing installation was in the neighborhood of \$125,000, but the plant economics are such that this expenditure is amply justified. Not the least interesting advantage which this installation possesses is its ability to utilize any grade of coal available at lowest cost. The plant is now operating on rejected coal, coal otherwise unsalable for steam railway or steamship uses, a supply of which is constantly available at Ashtabula.

Mill Engine.

The mill rolls are steam driven through a single set of pinions by a high Efficiency Nordberg Uniflow twin engine of 1500 hp. two cylinders 28 in. by 36 in. at 150 rpm—geared through Falk 5 to 1 reduction gears to a normal roll speed of 30 rpm. It is designed for a very flat load curve from 500 to 2000 hp. and a hand gear is provided for the purpose of backing off in cases of emergency. Fig. 2 gives an inadequate view of one side of this engine the reduction gears, steam headers

and separators. In the foreground will be noticed the main roll shaft.

Hyde Park Sheet Mill.

The sheet mill itself located in the main span is divided into two balanced sections—one-half on each side of the drive — each comprising two roughing stands, four hot stands and two cold roll stands (16 stands in all) built by the Hyde Park Foundry & Machine Company. The special engineering feature of this department is in the housings, which weigh 19 tons and have a special screw box arrangement. They are arranged so that the usual upper part is eliminated. This is a decidedly advantageous arrangement because very often serious delays are caused when the upper part of the screw box breaks or separates from the lower part.

The combined capacity averages between 5,000 and 6,000 tons of finished sheets per month. Unusual shearing facilities parallel these mills; six Hyde Park shears, motor driven, are now in operation together with one bar shear.

Two roller levelers take care of the blue annealed material.

Ample bar heating and sheet reheating capacity is provided through eight furnaces directly adjacent to the mill rolls.

Excellent crane service facilities rapid movements of production flow.

One Cleveland 30 ton crane with 10 ton auxiliary over the mills; one Cleveland 5 ton crane over the far bay; one Cleveland 10 ton crane over the furnace bay.

Fig. 4 shows the rear view of the heating furnaces with the hoppers for powdered coal and feed lines to furnaces.

Fig. 5 shows cooling racks in the foreground, annealing furnace in center and roll stands beyond.

The production of the mill flows in direct line from the squaring shears to the very large duplex annealing furnace.

Annealing Furnace.

The annealing furnace is a 12-car continuous double chamber under-fired recuperator type. In plan the furnace is divided into four sections. The sections comprise two annealing and two cooling chambers of three cars each. In operating, two cars are discharged simultaneously at certain intervals. Each half of the furnace is entirely independent of the other half and for this reason may be treated individually under operating conditions. The temperature of the compartments into which the cars first enter, is held uniform continuously. After the cars enter the cooling chambers, the temperature decreases as the cars approach the discharge end.

Recuperation or preheating of the air used for combustion is accomplished by passing it through conduits placed on continuations of the bridge walls in the cooling chamber and connecting with conduits in the stack flue, below the combustion chamber, in the annealing section. The air is subsequently mixed with the fuel in the burners.

The furnace is designed to utilize various forms of fuel, although in this instance pulverized coal is used exclusively.

One large bin divided into eight compartments is used for storing pulverized coal at the furnace. This bin is fitted with eight coal feeders, one for each burner on the furnace. Each coal feeder is direct connected to a variable speed motor through a speed regulator. Separate fans are provided for conveying the combustion air. The combination sheet and pair, galvanizing and boiler furnaces are similarly equipped.

The pickling tanks, washing machinery and all galvanizing equipment was manufactured by the United Engineering & Foundry Company.

A very interesting feature of the galvanizing operation is the design of the pot furnaces. These hot metal pots and their pulverized-fired furnaces are the only layout of the kind in the world. There are two spelter pots, one of 30 tons spelter capacity and one of 50 tons spelter capacity. The first has a production in galvanized sheets of approximately 30 tons per 24 hours and the second 60 tons per 24 hours. The galvanizing department is soon to be increased to six pots.

A varying proportion of the mill tonnage is finished through the corrugating rolls and the balance goes into commercial shipments as galvanized sheet or black sheet in all thickness from 1/80 to 9/65 of an inch thick and in sizes 40 in. wide by 144 in. in length. These sheets find their way into the manufacture of stove pipe, conductors troughs, metal ceilings, metal furniture, building sheets and roofs, automobile stock, etc.

Mill Buildings.

The mill main building shown in Fig. 7 is 624 ft. long by 166 ft. wide and is divided into three main spans, the main span is 66 ft. wide with two 50 ft. side

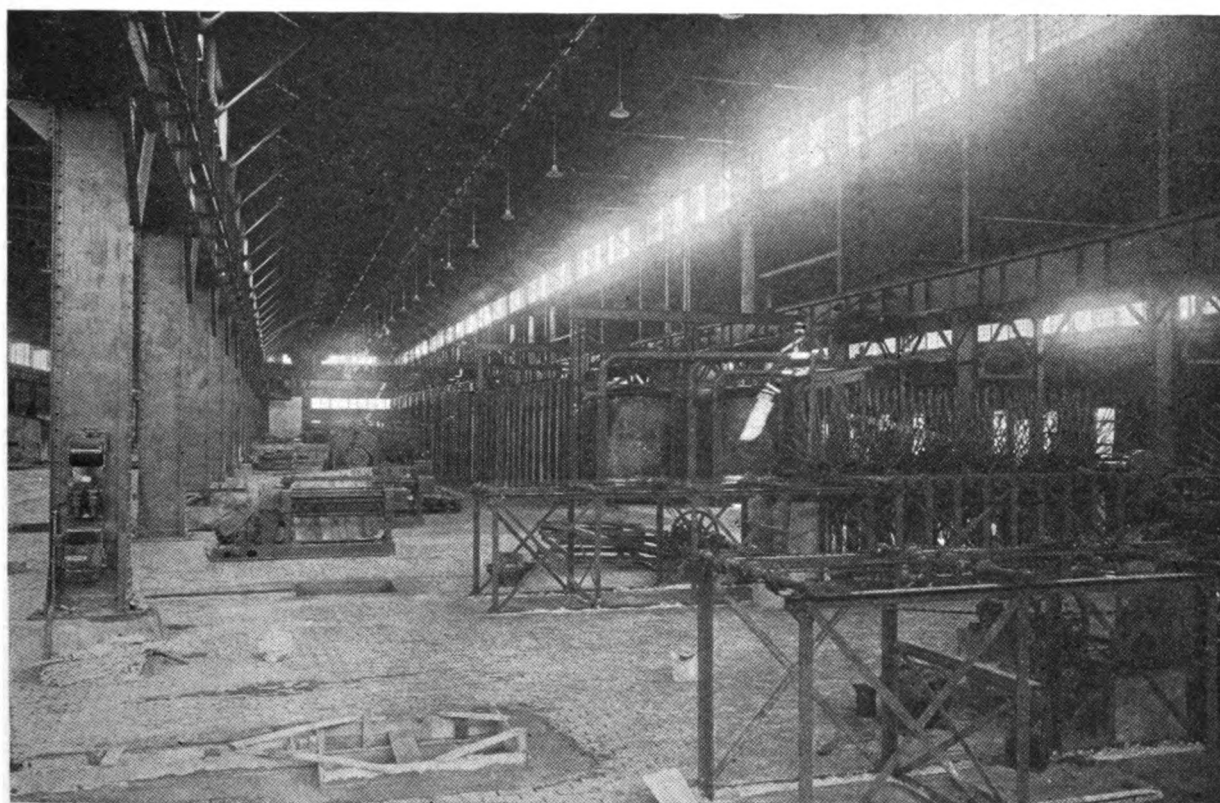


Fig. 5—Inside view of mill showing cooling racks in foreground, annealing furnaces in center and roll stands beyond the annealing furnaces.

spans. Built under contract by McClintic-Marshall Construction Company, it leaves nothing to be desired where comfort, accessibility and ventilation are considered. Because of the exceptional wind pressure noticeable in lake storms, the building is of high reinforced construction. The lighting arrangements are excellent—the result of a special study of sheet mill lighting requirements by Mr. McGaughey, the operating master-mechanic and electrical superintendent, who also designed and installed the entire electrical layout, switchboard and controls, which are a model of operating practicability.

Personnel.

Robert Lock, the President and General Manager of the Ashtabula Steel Company, is a man of wide experience in the sheet steel industry. He recently organized the highly successful Apollo Iron & Steel Company, designed the plant, and was largely responsible for its remarkably rapid development. E. H. Werner, associated with Mr. Lock as Chief Engineer in the design and construction of the plant, has many successful sheet mills as monuments to his genius and ability. The executive officers and operating officials are as follows:

H. M. Kunkle, treasurer; T. J. Rennick, secretary; E. J. Secrest, auditor; M. R. Gray, paymaster; W. J. Kunkle, assistant treasurer and purchasing agent; Severn P. Ker, sales manager; W. M. Hannum, chief clerk; C. W. Johnson, order department, and H. C. McGaughey, master mechanic.

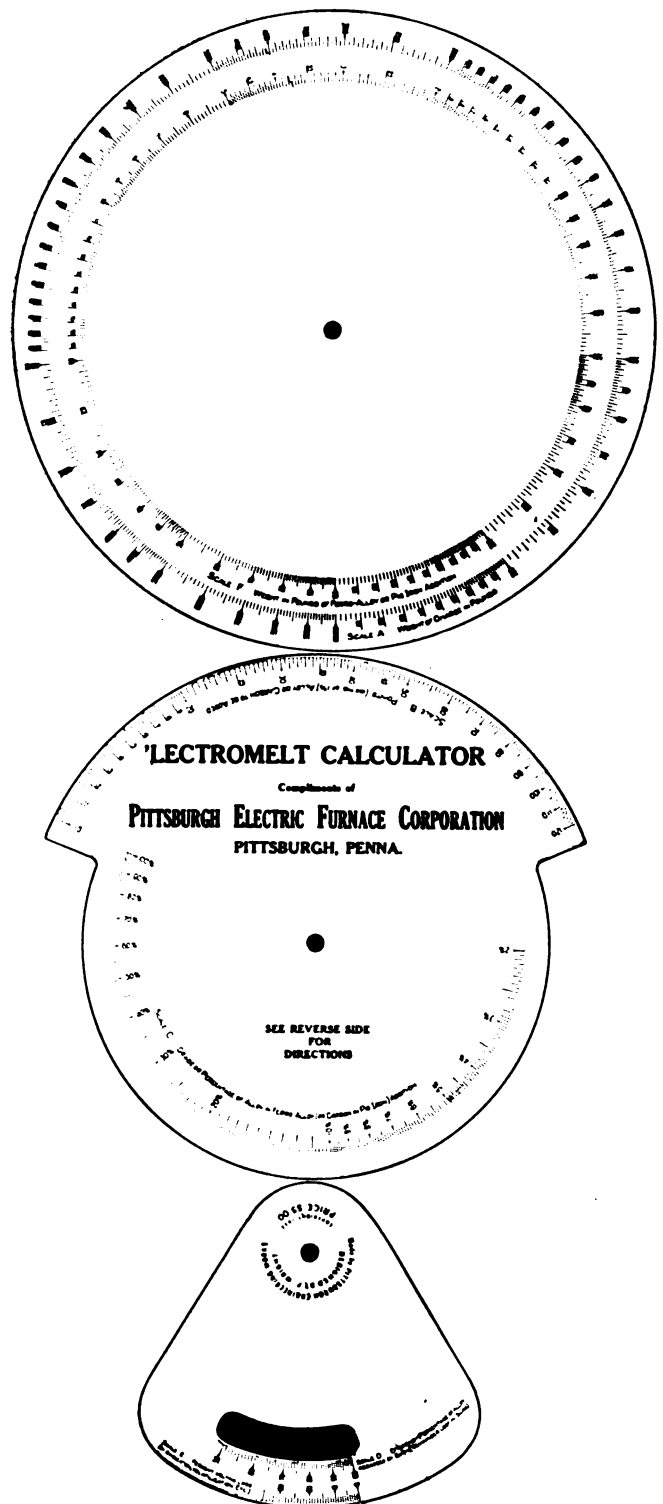
SLIDE RULE FOR CALCULATING ALLOY ADDITIONS

The Pittsburgh Electric Furnace Corporation, Pittsburgh, Pa., has developed a circular slide rule for calculating weight of alloys to be added in making various alloy steels. It is called the 'lectro melt calculator and is made from three celluloid discs as shown above. A replicate similar to the one which they are circulating, but somewhat smaller, may be made by mounting the above figures on cardboard, cutting out according to the outlines and the black oval in the lower figure, then pinning through the black dot. This device may be used by the furnace superintendent and melter in figuring mixtures and in allowing for ordinary percentages of loss in the absorption of the alloy in melting. The instructions which appear on the back of this slide rule are shown below:

Directions—Over the weight of the charge on Scale A set the number of points of alloy to be added on Scale B, holding these points together, over the grade or percentage of alloy in the ferro-alloy on Scale C, set the efficiency of absorption of the alloy on Scale D. Under the per cent of melting loss on Scale E, read the number of pounds of ferro-alloy required.

Example—Assume charge of 6,135 pounds. Assume necessary to add 14 points (.14 per cent) to bath, using 80 per cent ferro-manganese at 85 per cent efficiency of absorption and melting loss of 3 per cent in bath.

Calculation—1. Set figure .14 on Scale B over 6,135 on Scale A. 2. Set 85 per cent on Scale D over 80 per cent on Scale C. 3. Read opposite 3 per cent on Scale E alloy addition on Scale F, 12.3 lbs.



Circular slide rule for calculating alloy additions. Mount on cardboard and cut out. Cut out black oval and pivot through dots. Instructions for use of same are found in column opposite.

INDIANS PLANNING IRON EXPANSION

The largest iron and steel interests in India, the Tata Iron and Steel Works, are planning, according to reports received by the Department of Commerce, to enlarge their capacity by the end of 1923 to an output of 650,000 tons of pig iron and 425,000 tons of finished steel annually, a large increase over their present capacity of approximately 300,000 tons of pig iron and 125,000 tons of finished steel.

The Thermal Efficiency and Heat Balance of an Open Hearth Furnace*

Results of Investigation of Great Economic Value—Discussion of Gas and Air Ports—Comparison of Earlier Furnace Designs with Present—Waste Heat Recovery Through Steam Generation.

By C. L. KINNEY, JR.,† and G. R. McDERMOTT‡

BEFORE disclosing the subject matter of this paper, and in view of the economic significance of the subject involved, the authors' desire to present the following facts and suggestions for consideration by the members of the Institute.

The independent investigator of open-hearth furnace efficiency, in planning such work, is immediately confronted by the question of, not only what shall be observed and recorded, and of methods and interpretation of such observations, but also by questions of correctness of the values used in the calculations.

He also has to determine a scheme of tabulation of the data obtained, in such a form that the conclusion drawn shall make an emphatic appeal to those in charge of open-hearth plants and thus excite a larger interest in this important matter.

Considering the magnitude of the industry, there exist but few complete investigations of the subject, and practically all those published differ widely both in final form and in the thermo-chemical and thermophysical values used. It seems obvious to us that there exists a very great and important need that all work of this character should be carried on by standardized methods, values, and forms, which would make comparisons of results possible. It also seems evident to us that the adoption of such a code would do much toward awakening a greater interest in this matter, which would certainly be reflected by pronounced economies in the industry. We therefore suggest that, representing, as it does, the iron and steel industry of this country, it lies specifically within the jurisdiction of the Iron and Steel Institute to appoint a committee to prepare and sanction some such standard method of determining the thermal efficiency and heat balance of the open-hearth furnace, and we further suggest that those members, who manage such plants, pledge themselves to use in such investigations the standard method authorized by the committee. It is distinctly without our province to make specific recommendations concerning this code, but we feel that the method used by Mr. Fred Clements in his excellent paper on this subject, which appears in the *Journal of the Iron and Steel Institute* (London), 1922, Vol. CV, p. 429, is the most simple and practical of any extant, and for this reason we have in our presentation very largely followed his plan.

*Paper read before American Iron and Steel Institute, New York City, October 7, 1922.

†Superintendent No. 1 Open Hearth Department, South Works, Illinois Steel Company, South Chicago.

‡Assistant Chief Engineer, South Works, Illinois Steel Company, South Chicago.

The purpose of this particular investigation was to determine the present efficiency and heat balance of a typical open-hearth furnace as operated at these works and to show what improvements have been made and wherein the losses shown may be minimized. With this in mind we show a design of a 100-ton furnace in which are embodied certain improvements revealed in the following text.

Regenerators.

The proposed 100-ton furnace, as will be noted, has been provided with insulated checker chamber walls only, but no increase of combustion chamber efficiency has been assumed. While it is unquestionably true that an increase in checker chamber temperature is followed by increased combustion temperatures in the melting chamber, we do not feel warranted with the data available in making a specific increase in melting chamber efficiency, but are satisfied to show that the heat conserved by this insulation is of advantage in our waste heat boiler only. It may be asked why the checker chamber roofs are not so insulated, thus further conserving heat. To this question we will reply by saying that the peak temperature in these chambers is at present not far below the softening temperature of fire-brick and it is felt that any great increase would involve chamber roof collapse.

In an open-hearth furnace the two main features which make its operation possible are the regenerative chambers and a port arrangement, capable of producing a high temperature flame within the melting chamber.

The fundamental principles involved in regeneration of heat, by means of checker work, have been so many times stated, that a repetition of them is not considered necessary. It unfortunately is true that too many open-hearth furnaces are operating with checker work which in part only uses these basic theories, and in consequence their efficiency is low.

It should be borne in mind in designing checker work and chambers that to merely remove from the outgoing gases a very large proportion of their sensible heat does not mean high efficiency in the melting chamber, because the production of a high temperature fuel column is in part a function of high temperature incoming air and gas, and such temperatures cannot be reached if the sensible heat of the waste gases is dispersed over too great an area. From this it is obvious that the most efficient checker must have in its upper section the maximum concentration or intensity of heat that will permit incoming gas and air to reach the ports at the highest possible temperature and at the same time in the bottom section to discharge the

waste gases at a low temperature. A strict application of the foregoing principle would of necessity lead one to design a deep checker chamber of small horizontal cross section and the checker work itself with very small flues; for it is also a fundamental principle in heat transfer of this nature that the highest efficiency is obtained the more nearly we can approach the critical velocity of the gas used.

The commercial as opposed to the purely technical aspect of the deep checker work and small flue are as follows: The deep chamber involves an increase in charging floor height, if ground water is to be avoided, which adds to building cost and in addition consumes, in the form of energy necessary to put up on the charging floor the raw material for steel making, probably more fuel than is saved; nor can there be any question of the added labor cost involved in the removal and replacement of such checker work. The very small flue area is objectionable from a practical standpoint, because in its upper sections it rapidly becomes clogged with oxides, and thus the efficient campaign of a furnace is reduced to an uneconomical extent. One is thus forced in the practical design of checker chamber and checker work to sacrifice a certain amount of theoretical efficiency, which is more than compensated for in the form of practical gain. The checker work shown in our drawing of the 1922 and 100-ton furnaces was designed to give the greatest possible inlet area (number of top openings per square foot of horizontal area) and the maximum square feet of exposed surface per cubic foot of checker brick, but also, in its individual flue area of thirty-six (36) square inches, gives a velocity high enough for a very excellent rate of heat transfer without premature clogging and consequent suspension of efficient operation. Thus, based upon local conditions and results obtained over an eight-year period, we feel that this practical compromise with theoretical considerations represents for us the best available type, and so have used it in the 100-ton furnace. Specifically the net gain in efficiency represented by this checker work and expressed in actual pounds of coal per ton of ingots is as follows: Period of 1912, with checkers shown in Fig. 1 and burning Universal mine run coal, which has an average proximate analysis as follows: Volatile, 35 per cent; fixed carbon, 45 per cent; ash, 8 per cent; moisture, 12 per cent; Btu., 11,445, the average coal per ton of ingots produced was 750 pounds, and over an equally long period during 1914, using the improved checker work and the same coal, the pounds per ton of ingots was reduced to 684, a decrease of 8.8 per cent. Had we been using, during the periods named, what may be termed a standard gas producer coal of high fixed carbon, low ash and moisture content, having a heat value of 13,400 Btu., our coal per ton of ingots would have been for the 1912 period, 600 pounds and for the 1914 period, 548 pounds, this last figure representing actual results. It should be unnecessary to mention the desirability of the proper arrangement and size of flues under the checker work, and in the design shown we have attempted to minimize short-circuiting by progressive increase in area from bridge-wall to valve flue, at the same time keeping ample area in all parts in order to take care of deposited oxides. Ample insulated flue area, between regenerative chamber and valves and boiler, has also been provided.

Gas and Air Ports.

The area of gas port, or ports, is determined by the proper velocity of gas used. This area varies with the

character of the gas; a low Btu. gas having a high hydrogen and water vapor content and consequently a larger volume per unit of heat, naturally requires more area than a gas made from a better coal.

The air port area is in proportion to the theoretical air necessary to burn the gas plus a certain minimum excess. The location of the bottom of the gas port should be high enough to prevent partially unburned gas from coming in immediate contact with the bath, thereby delaying combustion. It should be noted in this connection that the modern furnace by providing a combustion space for the incoming gas is in marked contrast in this respect (delayed combustion) to some older types. Yet today it is not unusual to find furnaces, the face of whose gas ports are too far advanced into the melting chamber and the bottoms of the ports not high enough above the bath level. Inspection of an empty bottom, where such an arrangement of gas port is used, reveals the end banks extending an abnormal distance into the crucible (bath space). The antithesis of such a condition prevails where gas ports are set too far back, thus causing a very high temperature flame to play upon the pass over the end banks. With this condition these banks will soften and cut instead of building out and trouble will be encountered in the form of delays in repairing them, and in the loss of heats.

The correct proportioning of gas and air ports and their relative locations, etc., are based, fundamentally, upon a desire to obtain the most intimate mixture of the two gases as quickly as possible. However, the problem is further complicated by the necessity of directing the intensely hot flame thus produced so that in its relation to bath surface, it shall give up heat mainly by conduction and at the same time be kept away from the side walls and roof of the melting chamber. In the later type of furnace, the gas ports have been so placed that the so-called flame temperature of the stream of entering gas is not reduced by immediate contact with the bath to a point which inhibits an efficient further flame propagation. Having thus provided a hotter fuel column, it follows that provision must be made for its proper direction. Mere increase in velocity at or adjacent to the point of preliminary combustion is inadequate and it is thus necessary to resort to a reduction of area well in advance of this zone to prevent velocity dispersion and an uncontrollable fuel column. Reference to Fig. 1 Port End will show that in this early type of furnace, while a preliminary combustion zone existed, there was a decided lack of contact area between incoming gas and air. A cross section of the combustion chamber at the gas port mouth shows that only the upper portion of the producer gas column is in contact with the air column. Fig. 2 shows how this area of contact has been increased by the admission of air on the sides of the gas port.

Referring again to Fig. 1, it will be noted that, after leaving the zone referred to in the preceding paragraph, the area of greatest confinement was 43 square feet, and the continuity of direction and compactness of the fuel column was largely a matter of velocities and confinement in the zone immediately adjacent to the gas port mouth. Any attempt to increase fuel and air contact areas by adopting the plan of preliminary combustion, while maintaining 43 square feet as the area of greatest confinement, would have been followed, perhaps by better flame propagation, but certainly by a high temperature fuel column, which lack-

ing direction, would have unquestionably destroyed the roof and side walls in the course of a short campaign.

To maintain the proper direction and compactness of the fuel column under the 1922 condition of preliminary combustion, it was necessary to prevent velocity dispersion, by decreasing the area of confinement to 20 square feet, which is practically the amount indicated by the increased volume of the gases, due to their temperature increase between the face of the entering port and the point of greatest confinement. Not only does this decrease in area (23 square feet) result in a regular compact fuel column, but by increasing the intimacy of the mixture of gas and air an improvement in combustion is attained. Such reduction in area does not, as might be supposed, affect the efficient removal of the products of combustion from the melting chamber. With a furnace of this type, there exists, however, a limit in the input energy in the form of gas, lower it is true than in the 1912 type, but by no means the ultimate. In all probability this limit is a function of the amount of air capable of being delivered to the melting chamber by the stack effect of uptakes and checkers, against the melting chamber pressure. The ideal furnace must retain those features which promote partial and complete combustion, compactness and direction of the fuel column, but should in addition make possible a greater energy input per unit of time, which by speeding up the process reduces heavy radiation losses per unit of fuel fired.

The 100-ton furnace not only increases intimacy of mixture for the necessary combustion, and the confinement of area necessary for efficient control of the flame, but in addition provides an outlet area capable of handling a greater input energy.

Slag Pockets.

Size should be such that the furnace campaign will not be shortened by premature filling. This rate of filling varies with the completeness of the combustion of fuel, character of charge, degree of permissible water-cooling and refractoriness of the brick. Air-cooling of division walls minimizes gas leakage. Air-cooling of wall between slag pocket and checker chamber reduces the danger of slag breaking through and clogging checkers and flues. Air-cooling of the bottom produces a physical change in the deposited slag which facilitates its removal.

The 100-ton furnace shows the air-cooling system connected to a fan which supplies air to the furnace. This arrangement increases circulation and renders cooling more efficient and adds sensible heat to the incoming air.

The 100-ton furnace shows a substitution of the damper type valve for the rotating water-cooled type and while there is no question of the superiority of the former due to its easier flow lines, there is also much less heat lost in the cooling-water and the absence of water vapor carried into the furnace from the exposed water of the seal. It is also thought inadvisable to attempt to show a specific increase in combustion chamber efficiency from such an improvement. It should be emphasized, however, that a valve of this type, used on the air flues, eliminates the short-circuiting of a larger or smaller portion of the incoming air to the stack flue, which in the butterfly type comes from faulty sealing of the valve tongue and entails losses more serious than commonly supposed.

Water Cooling.

The amount of useful energy which is absorbed from the furnace system by water-cooling devices has been and is a subject of polemic rather than practical discussion. In making a decision whether or not to water-cool, both commercial advantages and thermal loss should be carefully weighed, the one against the other. Consider, for example, the water-cooling of a gas port. It is granted without discussion that the highest possible temperature in the burning fuel column is a function of the temperature of the incoming gas and air, and that any absorption of heat will be followed by a diminished flame temperature and a consequent loss of efficiency. There is, however, another factor of prime importance in efficient open-hearth furnace operation, which has been mentioned in that section of the paper dealing with port construction, namely, flame control and direction, and its importance to heat transfer to the bath and the maintenance of brick-work. It seems obvious to us, while a dry port will produce a slightly higher flame temperature over a short life, that the time lost in repairs and the inefficiency of and damage done by a poorly controlled flame, before repairs are made, actually produces a far greater commercial loss than the slight reduction in flame temperature from a proper amount of water-cooling. Considerations of this character based on experience, have led us to adopt the cooling devices shown in the 1922 and the 100-ton furnace.

Waste Heat Boiler.

The waste gases from metallurgical furnaces, particularly those issuing from the open-hearth, present an excellent opportunity for utilization in steam generation by means of a waste heat boiler.

The first studies and installation of a waste heat boiler in connection with an open-hearth furnace were made at the Illinois Steel Company, South Chicago, during the year 1910 and upon the results then obtained have been based the rapid development and applications of the modern waste heat boiler.

The sensible heat in the gases after passing through the regenerators of an open-hearth furnace represent 30 to 50 per cent of the heat available in the fuel as fired.

The absorption of the heat content of these gases is largely obtained by convection which necessitates the travel of the gases at high velocity over the heating surface of the boiler. Consideration of the formula governing this phenomenon will develop the reason.

The rate of heat transfer for either fire-tube or water-tube boilers may be expressed in the formula:

$$R = \frac{H}{T-t} = a + b \frac{W}{A}$$

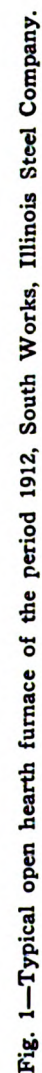
R = heat transfer rate in Btu. per hour per square foot of heating surface per degree F. difference in temperature.

H = Btu. transferred per hour per square foot.

a and b = constants.

$\frac{W}{A}$ = Mass velocity expressed as pounds of gas per hour per square foot of area of gas passage.

In order to absorb by convection, the molecules of the flowing gases come in contact with the heating surface of the boiler and impart their heat to it. The rate at which the heat is imparted to a unit surface



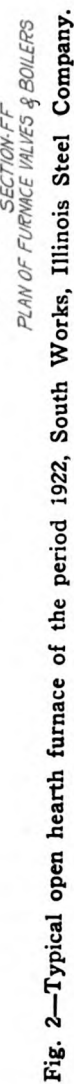


Fig. 2—Typical open hearth furnace of the period 1922, South Works, Illinois Steel Company.

depends, therefore, on the number of gas molecules coming in contact with it per unit of time.

By referring to the above equation of "R" for different tube diameters, it will be noted that the value of "R" not only increases with the reduction in diameter of the flue, but also with an increase in the ratio of

$\frac{W}{A}$, mass velocity. This absorption phenomenon mani-

fests itself to a greater degree when the gases are at or above their critical velocity.

The above phenomena and advantages also apply to economizers. During the past year, three fire-tube type of waste heat boilers, equipped with fire-tube economizers, were installed in connection with open-hearth furnaces, and the results obtained from both boilers and economizers further confirmed the theory outlined above.

By referring to Fig. 3 it will be noted that a fire-tube type of boiler and economizer is shown, of sufficient size to handle the waste gases leaving a 100-ton furnace. Both the boiler and economizer are constructed with 3-inch diameter flues.

The reduction of space required, lower first cost, less draft loss, elimination of air leakage due to infiltration, and ease of maintaining a clean surface on the gas side of the heating surface for equal evaporation lead to the adoption and installation of the fire-tube type of waste heat boiler at South Chicago in 1915 and in 1917.

In order to illustrate, by comparison, what may be accomplished for equal output by a boiler constructed with 2-inch diameter flues as a means of reducing the first cost and space requirements, a separate outline is shown on the same sheet of such a boiler and economizer. It is the belief of the authors that no difficulty will be encountered by the use of the 2-inch flues due to accumulation of dust in them. The relatively high velocity of the gases through the flues will tend to keep them clean; dust accumulation to any extent will be at the entrance of the flues on the bottom of the boiler. This dust can be readily removed periodically as the occasion arises.

The square feet of heating surface of the boiler and economizer constructed with 3-inch flues is 6250 and 2200 square feet respectively, while the square feet of heating surface of the boiler constructed with 2-inch flues and an economizer having 3-inch flues is 3100 and 2200 respectively. The latter installation would consume more fan power on account of the greater friction loss through the 2-inch flues as compared with the 3-inch flue. The cost of this power would be offset by the difference in first cost of the installation and interest on the investment.

Attention is called to the table compiled and shown in Fig. 7 which gives the "Overall Thermal Efficiency of the Utilization of the Coal Burned" in operating an open-hearth furnace with and without a waste heat boiler. The furnace equipped with a waste heat boiler utilizes as useful work 35.9 per cent of the energy in the coal fired at the producers, as compared to 16.1 per cent with the furnace not so equipped. This difference would be further increased by the installation of an economizer.

Gas House.

A modern gas producer plant has been shown, in which are provided mechanical producers, large insu-

lated gas mains and a covered coal storage. Four 10-foot mechanical gas producers are provided, with top poking and leveling apparatus, bottom agitation, ash removal and disposal. The peak gasification thus provided for using a mine run coal of the following natural proximate analysis (volatile, 35 per cent; fixed carbon, 44 per cent; ash, 8 per cent; moisture, 13 per cent), is approximately 27 pounds per square foot of effective grate area per hour, which is well within the limits of efficient continuous operation of a modern producer. It is true, that if a better grade of coal were used the capacity provided is excessive, yet if consideration be given to the gradually decreasing quality of gas coals and the irregularity of the coal mining industry, it was felt justifiable to provide an ample margin of safety in gasification rates. The enclosing of the coal storage bin is shown and recommended on the basis of thermal losses arising from excess extraneous water in the fuel.

Thermal Efficiency and Heat Balance Test.

In order to collect and observe the required data to confirm the soundness of the before outlined theories pertaining to regeneration and combustion, it was necessary to determine the thermal efficiency of a furnace designed along the lines of these theories and compare by the same method the performance of a furnace not embodying the principles as outlined. In addition to the determination of the thermal efficiency a "heat balance" was made to show the distribution of the thermal energy, from which further changes may be made leading to greater economies.

To collect the basic data, observations were made on three successive heats on Furnace No. 24 at Open-Hearth No. 2, South Works, Illinois Steel Company, which we considered was approximately at a point in its campaign representative of normal furnace conditions. On account of the necessity of calibrating the instruments and co-ordinating the efforts of the personnel engaged in observing and recording the required information, the results of the observations taken on the first two heats were considered only as preparatory work.

During the test a detailed log was kept of the furnace charge and operation. The weight of the coal fired in the five gas producers was accurately weighed and sampled. Both incoming charge and the product, in which were included ingot butts and scrap on the pit side and all slag, were carefully weighed and sampled. The furnace crucible (bottom) was practically free from slag and metal both at the beginning and end of the test heat.

All pyrometers were calibrated before the test at the company's pyrometer laboratory. During the test the pyrometers measuring the temperature of the incoming and outgoing gases were checked by an optical pyrometer sighted on silica and fire brick closed tubes which projected into the path of the gases.

A large orifice was installed in a 42-inch air duct leading to the air valve of the furnace. A very sensitive and accurate air meter which recorded the differential pressure across the orifice was loaned us through the courtesy of The Bailey Meter Company of Cleveland, Ohio.

Conclusion.

In the preceding text we have dealt to a large extent with such theoretical and general considerations as seemed to us supremely important in open-hearth furnace design and operation. Such important matters as fuels, gas producer design and operation, slags and

the relative value of different processes and their effects upon efficiency, necessarily remain untouched.

Fig. 3 is a graphic record of the principle temperatures, air flow to furnace and coal log covering the period from tap to tap.

The heat balance shows a total heat input of 531 million Btu. in the coal fired in the gas producers, of

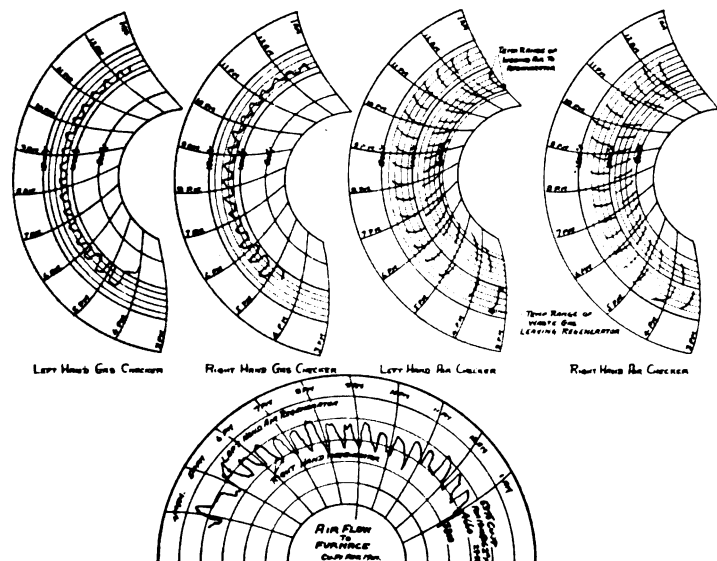


Fig. 8—Graphs of temperature, coal consumption and air flow, Heat No. 24565, September 26, 1922.

which 493 million Btu. was delivered to the furnace gas valve, no allowance being made for the tarry vapor content of the gas.

Of this 531 million Btu., the principle losses were:

Losses	Millions of Btu.	Loss in Per Cent of Coal Fired
Carbon monoxide in waste gas sampled at port ends.....	53.5	10.01
Heat radiated from checker chambers, slag pockets and uptakes...	38.8	7.3
Total heat absorbed by cooling-water (not including gas valve).....	71.75	13.5
Heat absorbed by gas valve.....	10.75	2.0
Heat in waste gas to boiler.....	270.00	51.0

The heat in useful work in the steel produced amounted to 85.29 million Btu. or 16.1 per cent of the Btu. contained in the coal fired. The net heat recovered by the waste heat boiler, after deducting the heat in the steam used for blowing the five gas producers was 87 million Btu. or 16.4 per cent of the Btu. in the coal. The large losses in cooling-water have been discussed in a preceding part of the paper.

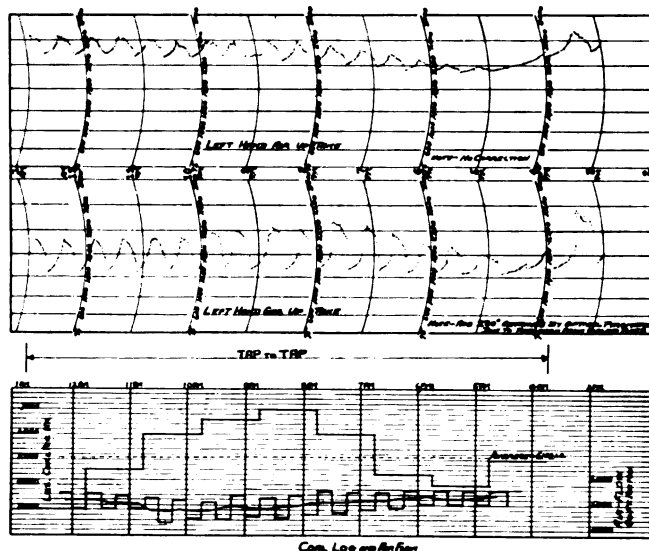
The apparent loss in the form of unburned carbon monoxide is in part recovered by secondary combustion in the checker chamber and largely appears as additional heat in the waste gases utilized by the boiler. This large loss to the furnace is uneconomical from the standpoint of furnace efficiency, and may be corrected in a large measure by improving melting chamber combustion.

Some 38.8 million Btu. are lost by radiation from checker chambers, slag pockets and uptakes, and we would expect in the 100-ton furnace to prevent a portion of this by insulation of the checker chamber walls.

The gases leaving the waste heat boiler can be further utilized by means of a feed water economizer to the extent of approximately 8 per cent additional steam

generation, as demonstrated by a recent installation at these works.

In detail data of the efficiency of two different types of furnaces it will be noted that two thermal efficiencies are shown, the higher representing bath efficiency based upon the fact that, by oxidation, the carbon content of the bath is reduced to carbon monoxide and



contributes heat to the bath by such a thermo-chemical reaction. The lower efficiency figure is based upon the belief, that the carbon monoxide thus produced, after escaping from the bath, should in a large measure be burned in the melting chamber. Upon this basis, we feel justified in assuming that if the major portion of carbon monoxide so produced is not burned in the melting chamber, it indicates defective combustion and naturally a reduced efficiency. For these reasons, we have charged against the furnace in the low efficiency figure the equivalent energy in the carbon monoxide if burned to carbon dioxide.

Referring again to Fig. 3, it will be noted, that the air flow as registered by meter indicated unequal air delivery to the opposed air chambers to the extent of approximately 20 per cent; and in addition failed to show any increase in the air input over those periods during which the greatest amount of coal was fired and the maximum volume of carbon monoxide was being evolved by the bath reactions. But what is more striking, the recorded air flow shows a reduction in the air delivered during those previously named periods, presumably due to a lack of stack capacity on the outgoing end of the combustion chamber. In the 100-ton furnace an attempt is made to partially overcome this deficiency, by increasing the outlet area of the melting chamber approximately 100 per cent, through the raising of a damper at this point.

To further an increase of efficiency in this respect, we propose to install a fan or other mechanical means of delivering air, and which is automatically controlled to supply air for effective combustion. The automatic control feature will supply air in proportion to the fuel consumed. This air control will operate in combination with an automatic control of the removal of the waste gases which must maintain a balanced draft in the melting chamber.

The need of providing a means of supplying the proper amount of air for combustion as demanded is emphatically shown by the ratio of fuel burned. It is apparent from the analysis of the waste gases and the record of the air flow meter, Fig. 3, that the stack effect of the air regenerators and uptakes cannot be depended upon at all times to supply the required air for efficient combustion. Needless to say this condition will exist regardless of the means employed for mixing the two gases before combustion takes place, although it is of course necessary to produce an intimate mixture of the two gases as well in order to obtain efficient combustion.

The following table gives a comparison of the important dimensions of the three types of furnaces discussed; and as a matter of additional interest we show the same data for the 100-ton furnace designed by Mr. Fred Clements of Rotherham, England.

The utility of a theory or theories can in general be said to be proven, or not proven, by the commercial result of their application over long periods of time; and we submit the following figures of pounds of coal per ton of ingots produced at these works during the periods covered by the text, as further proof of the soundness of the theories advanced.

UNIVERSAL NO. 4 MINE RUN COAL

Btu. per pound by calorimeter = 11,445

Proximate Analysis (natural) per cent.

Volatile	Fixed Carbon	Ash	Moisture	Sulphur
35.35	44.50	7.60	12.55	1.54

Period of 1912, pounds of coal per ton of ingots = 750.

Period of 1914, subsequent to improvement in checker work, pounds of coal ton of ingots = 684.

Period of 1922, subsequent to improved port and melting chamber design, pounds of coal per ton of ingots = 596.

Had the works been fortunate enough to have been supplied at all the periods named with what may be termed a standard gas coal, the pounds of coal per ton of ingots would be shown in the following figures which are confirmed by the actual operating results obtained during fairly long periods, when we were supplied with such coal.

LYNCH MINE RUN COAL

Btu. per pound calorimeter = 14,000

Proximate Analysis (natural) per cent.

Volatile	Fixed Carbon	Ash	Moisture	Sulphur
36.65	56.45	4.25	2.65	0.54

Period of 1912 = 600 pounds

Period of 1914 = 548 pounds

Period of 1922 = 477 pounds

In closing it is desired to express our appreciation of the care and interest taken by all participants in this work, both in observation, tabulation and drawings.

NATIONAL EXPOSITION OF POWER AND MECHANICAL ENGINEERING

The exposition covers the field of power and mechanical engineering from the moment the coal is taken from the ground until the power is turned into work in the final machine. Not only will there be representatives of prime movers and steam generating devices but also exhibits of manufacturers who have devoted their efforts to the solution of the troublesome problems involved in burning fuel and making and using power, whatever the industry requiring the heat and power derived.

The educational value of the exposition will be heightened by a series of models showing developments of large central power stations from the old Pearl street station, the first in this country, to the present Hell Gate station. Each of the exhibitors is planning to have apparatus shown in motion or diagram which will enable the fundamental principles to be easily discovered.

A list of exhibitors (to date) who will exhibit at the National Exposition of Power and Mechanical Engineering, Grand Central Palace, December 7 to 13:

Allen-Sherman-Hoff Co.	King Refractories Co.
American Arch Co.	Kingsbury Machine Works
American Refractories Co.	Ladd, Geo. T., Co.
American Society Mechanical Engineers	Leather Lined Iron Pipe Co.
American Steam Gauge and Valve Co.	Leather Belting Exchange
Ashton Valve Co.	Leddell Metals Co.
Bailey Meter Co.	Liptak Fire Brick Arch Co.
Baker, R. & L., New York Corp.	London Steam Turbine Co.
Beaumont, R. H., Co.	Lopulco Systems
Bernitz Furnace Appliance Co.	Lunkenheimer Co.
Bethlehem Shipbuilding Corp., Ltd.	McLeod & Henry
Bishop & Babcock	Mack Engineering & Supply Co.
Boig & Hill	Manning, Maxwell & Moore
Bowser, S. F., & Co.	"Manufacturers Record"
Burhorn, Edwin Co.	Martin-Morse Corp.
Carling Turbine Blower Co.	Merritt, L. R., & Co.
Carlyle-Johnson Machine Co.	Midwest Engine & Supply Co.
Cash, A. W., Co.	Mineral Oil Paint Co.
Celite Products Co.	Murphy Iron Works
Cochrane Corp., H. S. B. W.	Nash Engineering Co.
"Combustion"	N. A. S. E.
Combustion Engineering Corp.	"National Engineer"
Connelly, D., Boiler Co.	Olsson Corp.
Connery & Co., Inc.	Otis Elevator Co.
Coppus Engineering & Equipment Co.	Philadelphia Gear Works
Craig Damper Regulator Co.	Pittsburgh Testing Laboratory
Crane Co.	Pittsburgh Valve, Foundry & Construction Co.
Davidson, M. T., Co.	"Power"
Dearborn Chemical Co.	Power Specialty Co.
DeLaval Separator Co.	"Power Plant Engineering"
DeLaval Steam Turbine Co.	Pratt & Cady Co.
Detrick, M. H., Co.	Pyramid Iron Products Corp.
d'Este, Julian, Co.	Quigley Furnace Spec. Co.
Diamond Power Specialty Co.	Racine Machine Tool Co.
Drake Non-Clinkering Furnace Block Co.	Rahmann, Geo., & Co.
Edward Valve Mfg. Co.	Reading Steel Casting Co.
Ellison, Lewis C.	Reliance Gauge Column Co.
Engineer Co., The	Republic Flow Meters Co.
Erdman Forced Draft Burner Co.	Roto Co.
Falls Engine Stop Co.	Ruggles-Klingeman Mfg. Co.
Flinn & Emerich	S. C. Regulator Mfg. Co.
Foster Engineering Co.	Sanford-Riley Stoker Co.
Foxboro Co.	Scovill Mfg. Co.
Frederick Iron & Steel Co.	Schaeffer & Budenberg Mfg. Co.
Furnace Engineering Co.	Smith & Serrell
Gibby Engineering Co.	"Southern Engineer"
Gillis-Geoghegan, Inc.	Spence, Paulsen Co.
Graver Corp.	Stewart-Sayer Co.
Green Engineering Co.	Superheater Co.
Griscom-Russell Co.	Sweets' Engineering Catalog
Harris, Burt	Tagliabue, C. J., Mfg. Co.
Hays, J. W., Co., Inc.	Templeton Mfg. Co.
Hill Clutch Co.	Tidewater Oil Sales Corp.
Huber-Hand Stoker Co.	Tracy Steam Purifier Co.
Hunt, C. W., Inc.	Uehling Instrument Co.
Huyette Co., Paul B.	Underfeed Stoker Co. of America
"Industrial Management"	Underfeed Stoker Co. of Canada
"Industrial Power"	U. S. Cast Iron Pipe & Fdry. Co.
International Filter Co.	Vibration Specialty Co.
International Combustion Engr. Corp.	Vincent Gilson Engr. Co.
Jenkins Bros.	Walworth Mfg. Co.
Kelly Valve Co.	Watts Regulator Co.
Keasbey & Mattison	Wheeler, C. H., Mfg. Co.
Kieley & Mueller	Wheeler Condenser & Engr. Co.
	Yarnall-Waring Co.



Removal of Solid and Liquid Particles From Gases

By A. F. NESBIT*

SYNOPSIS

Combustible gases which are to be used as a source of heat or motor fuel, usually hold in suspension dusts or other particles which clog up mains, check work, and passage ways, or cause abrasive action on machined parts and interrupt the operation of motors.

For given weights of solid and liquid particles originating during chemical and manufacturing processes, many particles may present vastly different surface areas to the gases in which they are held in suspension. The carrying capacity of gases for these particles, for given velocities, may be very different, and the removal of one kind of particle from the gas stream presents a more difficult problem than the removal of another kind of particle.

Gases which are the product of combustion, partially completed, may contain solid and liquid particles of a redeemable value, or the discharge of these particles into the air may be injurious to health and vegetation, or may be declared a nuisance.

A brief description is given of experiments in removing dust from blast furnace gas, and pitchy and tarry particles from combustion gases.

Types of combined electrical and centrifugal, and of centrifugal gas cleaners are described.

Applications of these forms of cleaners are suggested for the removal of ash from hot and cold powdered coal combustion gases, also from producer gas. The recovery of hot cement dust from kiln gases and the utilization of heat in dust and in the gases in a special form of waste heat boiler or economizer are suggested. Application is made to the stage by stage recovery of several prominent soft coal by-products, and to the extraction of naphtha from natural gas.

THE cleaning of combustible gases may have for its object the preparation of the gas for service; first as a heating fuel, and second, as a motive power fuel; and the cleaning of hot gases which are non-combustible, or which may be the product of combustion already accomplished, may be carried out for the purpose of using the heat energy of the gases for the development of steam in waste heat boilers, with or without the simultaneous recovery of a by-product or the elimination of a dust nuisance.

Combustible gases, which may serve as a source of heat, are in many cases more desirable as a fuel, if their entrained dust and solid particles have been removed before they enter the combustion chamber of the apparatus used. Gases of this type have been cleaned very effectively by the washing process; but during the cleaning stages there has been a large loss

of heat to the water employed, and a consequent lowering of the temperature of the gas. This low temperature cleaned gas, at the expense of its efficiency as a fuel, must now provide from its store of pent-up energy, as a chemical or mechanical mixture, the necessary source of heat that is required to raise its temperature to its original value before it entered the washer. A considerable saving of heat units may be effected by the use of a dry system of cleaning with a minimum change in temperature.

Combustible gases to be used as a motive power fuel, as in gas engines, must be effectively cleaned of entrained dust or other particles which in any way may interfere with the operation of the engine, or give rise to excessive wear of its parts and possible interruption of its operation. Washing processes have been very largely employed in the past, and serve the double purpose of cleaning the gas, while at the same time cooling

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it to any desired temperature, in anticipation of its admission into the explosion cylinders.

Hot gases which are noncombustible, and the heat which has not been utilized in any large way in the past, have been escaping into the atmosphere from all kinds of chemical, metallurgical, or roasting, and other processes, and little or no attempt, until within recent years, has been made to recover from its fumes waste products which have a redeemable value.

The fourth type of gas or air streams to be cleaned is that which contains in suspension solid and liquid

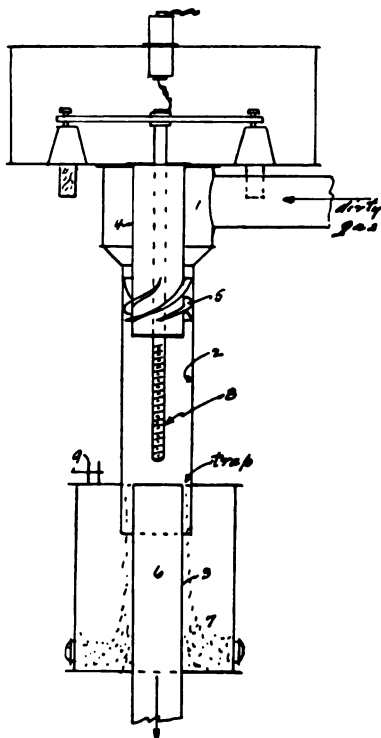


Fig. 1—Single unit combined electrical and centrifugal cleaner.

particles which have no appreciable redeemable value, but the escape of which into the atmosphere may be considered a nuisance, and be the cause of financial loss or possible litigation.

This article is intended chiefly to describe a type of apparatus which operates wholly upon mechanical principles or which may be combined to operate jointly with special structures constituting a combined mechanical and electrical gas cleaner.

The cleaning of gases coming under the individual requirements as here classified, necessitates a careful study of each case as a separate and distinct problem. This fact is appreciated when the physical and chemical properties of suspended particles is considered. The first of this series of articles referring to the mechanical type of cleaners, appeared in *The Blast Furnace and Steel Plant* in October, 1920.

The writer had the good fortune to have been associated with a special committee of engineers, under Mr. George E. Wisener, General Superintendent of the Mingo Works of the Carnegie Steel Company, at Mingo Junction, Ohio, in connection with research work on the application of the electrical precipitation process to the cleaning of blast furnace gas.

Tests of Combined Electrical and Mechanical Gas Cleaner.

During this study at Mingo Junction it developed that the most satisfactory method of automatically and continuously removing the dust from the grounded electrode pipe was by imparting a swirling motion to the gas stream and its entrained dust. The scouring action gave the best results, when the gas was admitted in a thin annular layer close to the stream boundary line. Fig. 1 makes clear the early form of apparatus used.

The gas velocities due to the varying gas pressure in the mains from which the dirty gas was taken, varied through wide ranges from 10 ft. to 48 ft. per second in the 8-in. diameter pipe.

The Apparatus.

With the apparatus shown in Fig. 1, the dust collecting chamber (7) would collect as much as 75 pounds of flue dust in an hour. The inner wall of the grounded electrode pipe (2) showed a clearly defined marking due to the scouring action of the swirling dust, and this marking extended to the lower end of this pipe. Electric current was supplied by a 5-kw., 50,000-volt, dc. generator of the Girvin type. This generator gave practically a sustained voltage and current wave so that all dust particles were charged to a definite voltage and at a definite polarity. The combined action of the centrifugal header supporting the stationary vanes (5), and the screw thread discharge electrode (8) was as follows:

The gas was free to expand radially inward at the lower edge of the six-in. dia. sleeve to which the stationary vanes (5) were fastened. The carrying capacity of gases is sometimes remarkable, and in this case such inwardly expanding gas carried with it a portion of the finer dust particles of ore and coke, and these particles by impingement upon the discharge electrodes, by the action of the electric wind from the screw threads and collision with previously charged particles, became charged with a definite polarity, and as such now constituted ionic dust streams which were driven into the swirling and scouring dust streams along the inner wall of pipe (2). At the upper edge of the clean gas discharge pipe (3), the annular dust stream along the inner wall of pipe (2) was sheared off from the central core or column of clean gas, and was collected within the chamber (7). The corona discharge from the rigid discharge electrode (8) was very uniform and intense, and the corona forming voltage and working voltage could be controlled very nicely.

Remarkable cleaning efficiency of the centrifugal header acting by itself and made up of the pipe sleeve (4) and the stationary vanes (5) of Fig. 1, and apart from an electrical equipment such as the discharge electrode (8) and its associated insulator and other structures, suggested a mechanical type of gas cleaner, with a wide range of possible applications. This type of mechanical gas cleaner with many modifications in structural form and method of isolating the dust from the clean gas, was suggested by one of my associates, Mr. Frank R. McGee, Chief Mechanical Engineer of the Carnegie Steel Works, at Mingo Junction, Ohio. Patents covering these ideas have been issued to Mr. McGee and other patentable material is under consideration or pending.

Mechanical Gas Cleaner.

The apparatus of Fig. 1 was stripped completely of

the electrical system, and provision was made for many adjustments of the position of the centrifugal head relative to the annular dust trap, the nozzle opening between the vanes, etc., and a series of tests made with this altered structure.

Any dust which passed out of this cleaner discharge pipe was collected by means of an electrical precipitator, except such dust as settled or was trapped in the short pipe connections between this structure and the precipitator. The dust collected in the chamber (7) of this apparatus (see Fig. 1) was weighed, and the total dust collected in the precipitator and connecting pipes was weighed. During these tests the electrical precipitator was operated so as to collect all dust that passed through the centrifugal cleaner and the connecting pipes. The ratio of the weight of flue dust caught by the annular trap, to the total weight of dust passing through the centrifugal cleaner, gave values as high as $97\frac{1}{2}$ per cent, as the efficiency of this type of cleaner in single units. These results could be repeated at will.

A rather exhaustive series of tests were conducted with apparatus similar to that shown in Fig. 1 and with

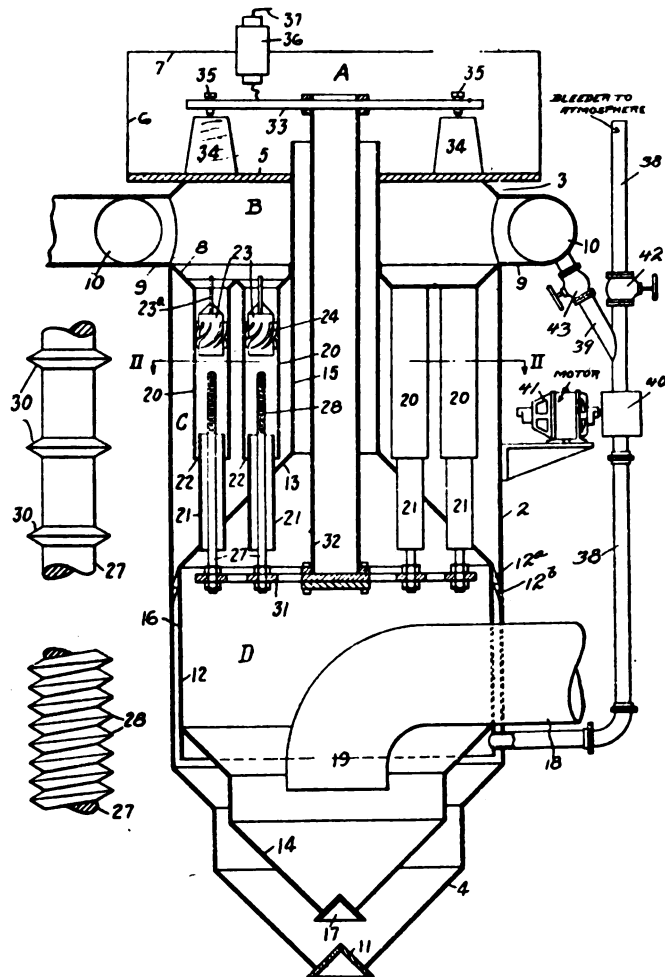


Fig. 2—Multiple unit combined electrical and centrifugal cleaner.

pipes (2) as large as 16 inches inside diameter. The results were in everyway comparable with those using the 8-in. diameter pipe structure of Fig. 1. During the coldest weather of the winter of 1917-1918, the 16-gauge galvanized iron pipes which were over 100 feet long and supplying dirty gas to the cleaner were exposed to atmospheric temperatures, and until the sys-

tem was well warmed up, for each day's run, the water vapor condensed in the apparatus was collected along with the dust and formed a wet mud in the collecting chamber.

Even though the unsettled conditions, which have effected business and the industries since the world

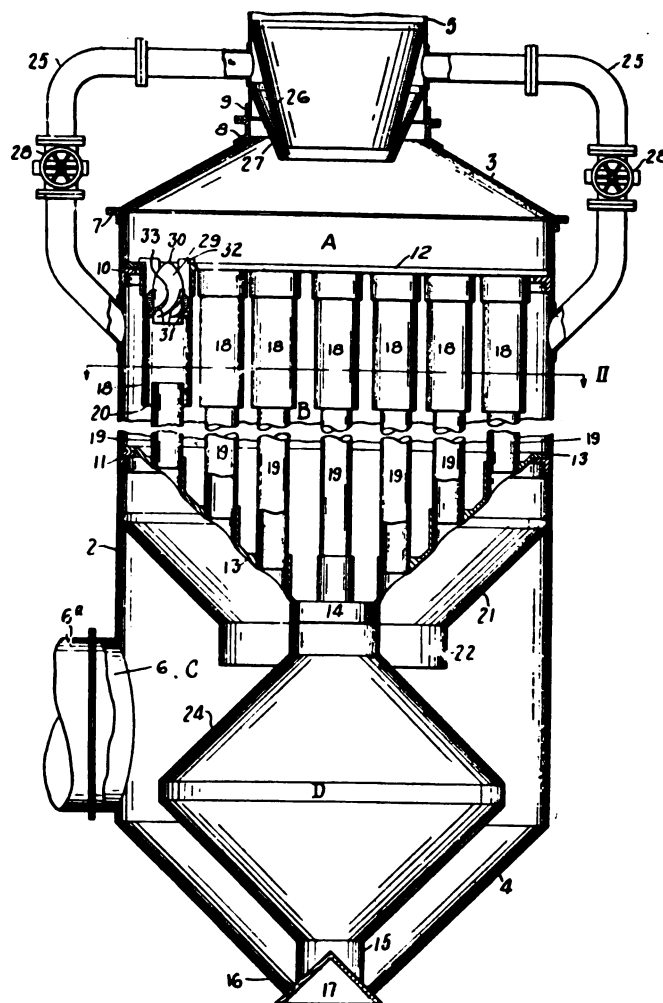


Fig. 3—Multiple unit centrifugal cleaner.

war, have given rise to regrettable delays and interruptions toward reaching a final form of this centrifugal type of structure for cleaning blast furnace gas, the work is, however, going on as rapidly as possible. Apart from work which has been done, up to date, at Mingo Junction, Ohio, the writer has been in close touch with, or actually conducted many additional tests with hot and cold gases which have contained solid and liquid particles, which have differed widely as to their physical and chemical characteristics.

Research Work on Pitchy and Tarry Products.

Tests which the writer has made with unit cleaners of this type have taken pitch and tarry gases cooled to temperatures as low as from 36 to 13 deg. C., and by slowly passing steam through a concentric jacket surrounding the pipe (2) of Fig. 1, the tar and pitchy products which had been thrown out against the inner wall of this pipe (2) was kept on the move, along with the water particles also present in the dirty gas stream, and both were thrown through the trap into the collecting chamber. This steam jacketing effect upon the inner wall was made only large enough to keep the layer of tarry and water particles in a thin layer and

on the move and so as not to produce an appreciable re-evaporation of these particles. For the automatic removal of pitchy, tarry and other distillate products, which would freeze to the pipe and the centrifugal header at these low temperatures, it is necessary to design the header so that it may be fed with steam or circulating water and properly drained.

Description of Multiple Unit Combined Electrical and Centrifugal Gas Cleaners.

Fig. 2 represents one proposed form of combined electrical and mechanical gas cleaner, made up of a multiple grouping of individual units. The gas enters the distributing chamber B and passes down through the individual cleaner units, the operation of each one of which is identical with that outlined for Fig. 1.

The electrical system of Fig. 2 is very rigid and compact, and equipped with an electrode system of short co-operating length, supplies an intense and almost solid static electric field through which the gas and its dust must pass. This short electrode system is particularly valuable, so that the swirling action may not be materially weakened due to a long travel, until the dust and other particles are safely sheared off from the central clean gas column.

In this structure of Fig. 2, the individual dust traps are properly connected and one communicating dust collecting chamber C, so designed that the discharge of the collected dust may be made automatic. All of the clean gas outlet pipes, from these individual cleaner units, discharge into one clean gas chamber D, from which one discharge outlet is shown. In both figures (1) and

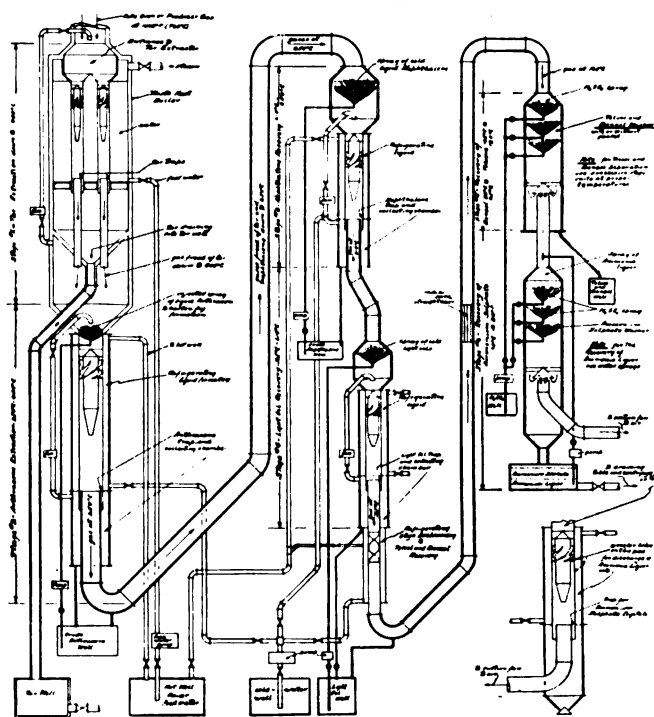


Fig. 4—By-product recovery.

(2), the pressure relief valves (9) and (43) respectively, make provision for keeping the gas pressure in the dust collecting chamber of such a value as to avoid a back pressure against which the dust must be discharged through the traps, or to avoid a dead air space. This pressure relief system may be preferably such as to recirculate such a portion of the gas as may be found necessary for the results required. This provision is made in Figs. 2 and 3.

Description of Multiple Unit Centrifugal Gas Cleaner.

Unit cleaners, of the type shown in Fig. (1), with properly associated concentric jackets for steam, or refrigerating brines, but stripped of the electrical system, do not remove as completely the dusts, tar and other fogs constituting the recoverable contents of the gas, as may be done by the use of the combined elec-

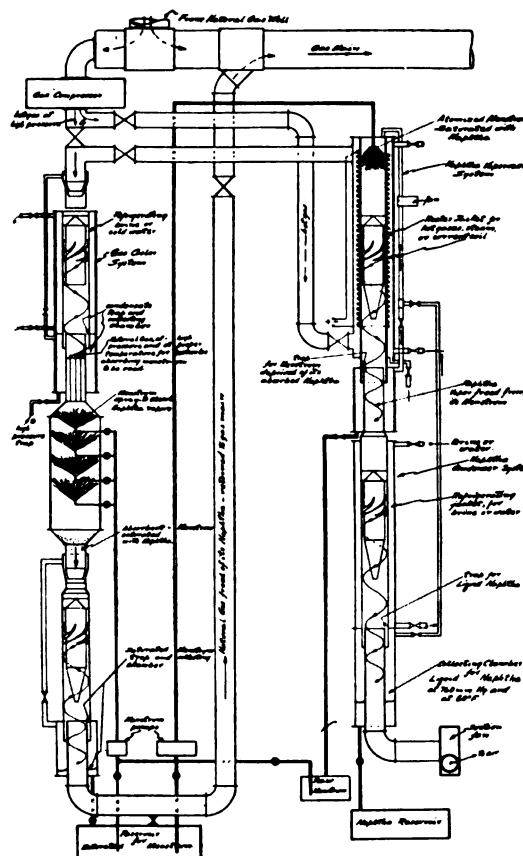


Fig. 5—Extraction of naphtha from natural gas.

trical and mechanical cleaners. The strictly mechanical unit cleaners are free, however, from the attendant disadvantages always present when using electrical systems, and they yield such a high percentage of recovery as to suggest a successive stage refrigerating type of apparatus, as will be shown later in this article.

Fig. (3) shows a mechanical cleaner, in substance, identical with that of Fig. (2), when the electrical system of the latter has been removed and the structure correspondingly simplified. In Fig. (3), A is the admission chamber for the dirty gas. The multiple grouping of the individual centrifugal cleaning units discharge the dust and clean gas into their appropriate collecting chambers, B and C just as was the case with the combined cleaner of Fig. 2.

In the suggested forms and groupings of cleaner units for the special problems which follow, each particular problem will have its own peculiar difficulties to be met and overcome. Modifications and refinements will necessarily have to be made in order to do the work required and these probable difficulties which may suggest themselves in advance of actual tests may not be insurmountable.

In addition to the applications suggested in the following paragraphs, the centrifugal structure is especially well adapted as a steam separator, an air dryer

(e) Makes possible the cleaning of gases at wide ranges of gas velocity, and depending upon the properties of the particles to be collected.

An Investigation and Discussion of Slag Formation on Boiler Tubes

Conclusions Arrived at After Extensive Tests—Boiler Operation and Methods of Preventing Slag Formation on Boiler Tubes.

By HARRY H. BATES*

THE trend of recent boiler and stoker development is toward the extremely large units, which are operated at capacities far beyond those that were considered normal a few years ago. The fact is that it is a daily occurrence to hear of boiler stations operating at 300 per cent of rating or more, and it is by no means unusual that 400 per cent of the rated capacity and more are reached.

These large boiler and stoker units with their large grate areas and high gas velocities caused by high capacities, have brought about problems that have reached considerable magnitude in the combustion field of engineering. Most of these problems have existed ever since coal has been used for fuel purposes for steam generation, but until quite recently the small, easily accessible units used did not serve to indicate the extent of the trouble that would be involved. With the introduction of the large units it has become necessary to study these problems, and experiment in furnace construction in order to eliminate, as far as possible, the difficulties encountered.

One of the most serious, as well as most baffling, of these problems is the formation of slag on boiler tubes. That this is a problem that can become serious is shown on Fig. 1, and it is to be stated that the slag shown was deposited in less than one week of operation, in spite of all the care and work done in attempting to remove it.

To determine the exact means by which the material is deposited and the chemical reactions that actually take place is a very difficult task, but after six months' investigation of the subject, certain deductions were arrived at. During the entire investigation it was constantly borne in mind that to effectively overcome the slag problem it would first be necessary to establish the cause of its formation, how it is carried up to the tubes, and the form in which it is deposited.

The Similarity of Causes of Clinker and Slag.

In discussing the problem of slag formation on boiler tubes, it is well that a brief discussion be given on the formation of clinkers in the furnace itself. The slag found on the boiler tubes and furnace walls is of the same material as the clinker that is discharged from the furnace, and the causes of one are to a large extent the causes of the other.

The principal constituents of ash are silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), ferrous oxide (FeO), ferric oxide (Fe_2O_3) and lime (CaO). There are other materials present, but they are in such small quantities that their presence and effect are practically negligible and will not be discussed in this paper. Table 1 shows the atomic weights of the principal constituents of ash as well as their fusing temperatures.

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TABLE 1—PRINCIPAL CONSTITUENTS OF ASH AND THEIR FUSING TEMPERATURES

Oxide	Formula	Atomic Wts.	Deg. F.
Silicon dioxide..	SiO_2	60.30	3227
Aluminum oxide	Al_2O_3	102.20	3416
Ferrous oxide...	FeO	71.84	2586
Ferric oxide....	Fe_2O_3	159.68	2840
Lime	CaO	56.07	3452

Table 1 is of particular interest because, with the one exception of ferrous oxide, there is not one of the principal oxides of which the ash is composed that will fuse at

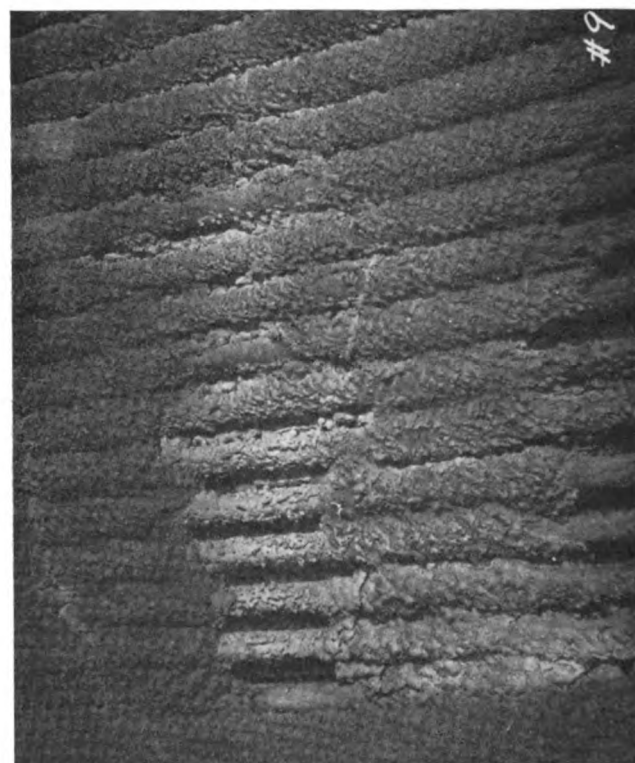


Fig. 1—Accumulation of slag on horizontal water tubes so heavy boiler became inoperative.

ordinary furnace temperatures alone. It is when these oxides are heated in intimate contact with each other that the real clinker forming properties present themselves. The basic oxides act as fluxes on the silica present with a lowering of the fusing temperatures of the combined material. The fusing temperature is dependent upon the oxides that are brought in contact with the silica and the proportion of each. These basic oxides, together with the silica, form monosilicates of the gen-

eral form of CaO (SiO_2), etc. These monosilicates have a very much lower fusing temperature than the oxides of which they are composed. As an example of this fluxing action, pure silica fuses at 3227 deg. F., pure ferrous oxide fuses at 2536 deg. F., but ferrous silicate fuses at

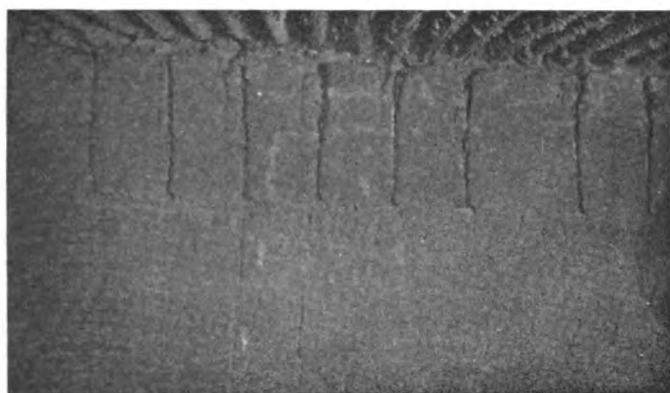


Fig. 2—Action of slag on boiler walls and tubes. Note the erosion of walls where C. I. hangers supported soot blower element.

2318 deg. F. If lime is added to this silicate in various proportions the fusing temperature may be anything down to 2066 deg. F. From the above it may be said that ferrous silicate alone, or in combination with lime up to about 40 per cent of the total ash, will give a fusing temperature well below ordinary furnace temperatures.

Tests made by the United States Geological Survey indicate that the tendency of ash to clinker is increased as the per cent of iron increases, but this may not be true invariably.

Iron combines with the silica in the form of ferrous or ferric oxides, but not in the form of sulphides; however, it is only a matter of supplying heat and oxygen to convert the iron into its ferric state.

The per cent of sulphur found in an ultimate analysis of coal is frequently blamed for the excessive formation of clinkers, but sulphur is not a slag forming material in itself. It is usually found in the fuel as sulphates or pyrites, which is ferric sulphide. The sulphates are not troublesome to a great degree, but the larger portion is in the form of pyrites and it is the iron in this combination that really is the disturbing factor.

The United States Bureau of Mines has made an extensive research of the sulphur forms in coals. Table 2 gives the relative proportions of the several forms, as obtained from their Technical Paper No. 254, by A. R. Powell.

It will be noted that the pyritic sulphur comprises from 40 per cent to 60 per cent of the total sulphur, except in the Pocahontas and Elkhorn coals, and these coals are generally considered very high grade steaming coals and give a minimum of clinker trouble. If sulphur accompanies the mixture it retains its form as ferrous sulphide and this material, in conjunction with silicious matter, makes an even more easily fusible mass than those already given.

Relation of Clinker Forming Properties of Ash to Formation of Slag on Boiler Tubes.

The above discussion of clinker formations also applies almost in its entirety to slag formations on boiler tubes and walls. The condition

Sulphur Form	Upper Freeport, Pa.	Pittsburgh, Pa.	Pocahontas, W. Va.	Elkhorn, Ky.	Coal Creek, Tenn.	Cherokee, Kan.
Pyritic sulphur . .	.47	.79	.08	.13	1.75	1.99
Sulphate sulphur .	.07	.23	.01	.04	.71	.32
Organic sulphur . .	.62	.66	.46	.51	1.78	.71
Total sulphur . . .	1.16	1.68	.55	.68	4.24	3.02
Per cent of Pyrites in total sulphur . .	40.5	47.0	14.5	19.1	41.3	66.0

is suggested that the iron must be kept in its ferric state, which is practically infusible. This can only be done by completely oxidizing the sulphur and iron before the tubes are reached. No free oxygen passes through a well broken up fire. (United States Bureau of Mines, Technical Paper 139, and Bulletin 135.) Unless excess air is added over the fire an incomplete combustion of carbonaceous matter and other oxidizable substances results. For this reason it can be considered with reasonable surety that complete oxidation of all slag forming constituents cannot be accomplished within the limits of the fuel bed proper. The inherent characteristic of the underfeed type of stoker to burn fuel more rapidly over the tuyere rows than over the retorts aids materially in supplying the required distribution of oxygen for the complete oxidation of all oxidizable matter, but, even with this type of stoker, slag formations on the tubes and furnace walls are a serious problem with some coals.

It can here be said that all types of stokers, underfeed, overfeed and chain grates, have difficulty with slag formations. Even a low velocity gas from a quiet fire on a natural draft stoker will carry quantities of this slag with it and deposit it on the tubes and walls.

How Slag Is Conveyed to and Deposited on the Tubes and Walls.

The above facts, especially those concerning the slag being carried to the tubes at all boiler ratings and gas velocities, suggest that the slag particles are carried up

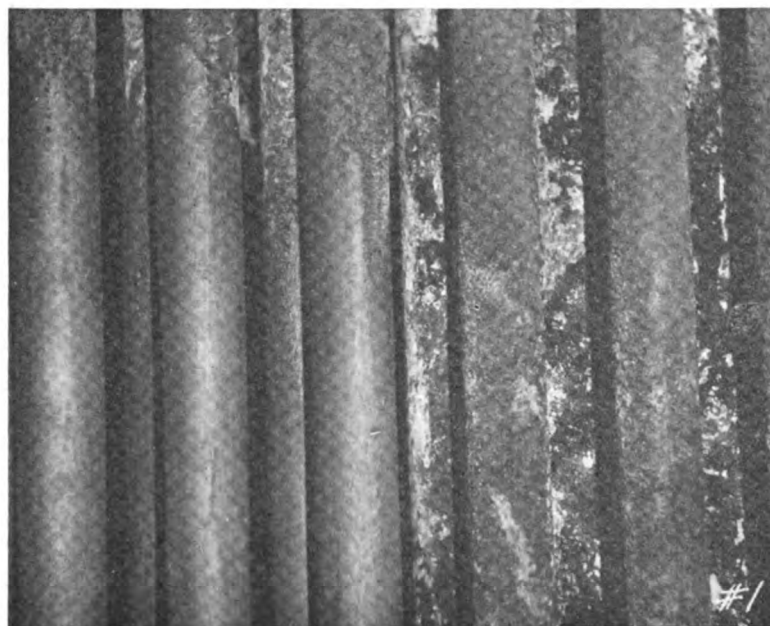


Fig. 3—Slag formation on vertical water tubes, showing left side tubes with slag scraped clear and right side tubes with slag knocked down.

with the draft in such minute form that they can be carried with the low velocity gas as well as the gas that rises rapidly. An examination of the slag under the microscope revealed small spherical globules which substantiated the belief that the particularly troublesome particles were the small ones.

When these little particles come in contact with the free oxygen in the furnace gas for a sufficient time to

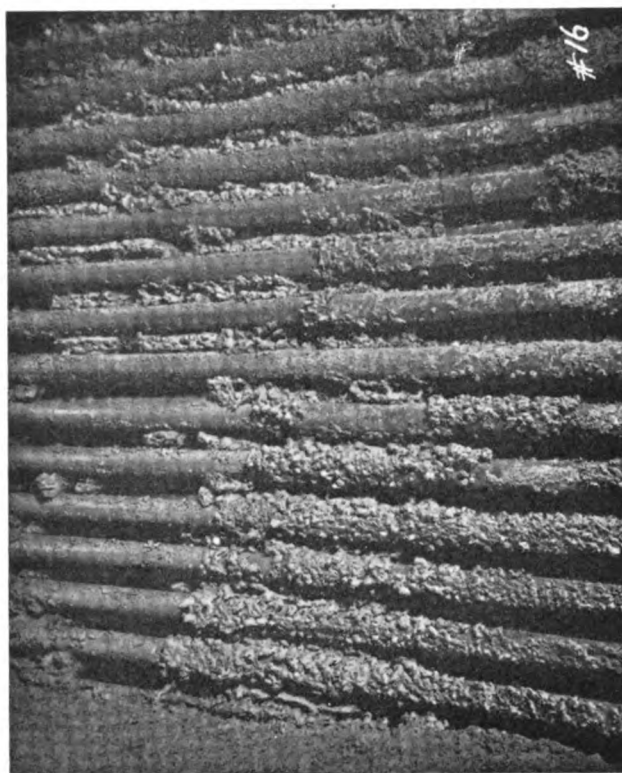


Fig. 4—Slag formation which badly interferes with passage of gases.

completely oxidize them they will be transformed into their completely oxidized state and become solid. If they solidify before touching the tubes or walls they are carried through the boiler as solid ash. On the other hand, it has already been pointed out that no free oxygen is obtained through the fuel bed. In this event the particles remain in a molten condition, on account of their low fusing temperature in their -ous state, and are deposited on the tubes and walls where they may either be completely oxidized and solidified or be covered by successive coatings or layers of the same plastic material. That the latter is true to a large extent is shown by layers of a very dark vitreous material covered by a reddish brown layer or protective coating. This reddish coating is largely ferric material and it prevents further oxidation of the dark ferrous material within by excluding the oxygen from it. A considerable portion of the material on the outer surface, especially on the tubes, is of a friable and non-fusible character, and it is of a completely oxidized nature.

Devices for Admitting Excess Air to the Furnace Gases and Their Effect.

A number of manufacturers of stokers and stoker auxiliary equipment have produced equipment for supplying excess air over the fire in order to completely burn combustible gases. They have undoubtedly accomplished some beneficial results, but, even now, there is yet considerable research and experimental work to be

done on the extra large, super-power station type of boilers. The extreme size of these furnaces make correct distribution of air to the furnace an extremely difficult problem to solve. The nearest approach to a suitable device so far developed is an installation with perforated cast iron air distributing boxes above the throat of the stoker.

Another type of equipment frequently used for this same purpose is the ventilated wall of perforated fire brick. This method is satisfactory for the ordinary size of furnace, but for the larger units a very strong jet action is required to force the air to penetrate the rapidly rising volume of gas to a distance sufficient to oxidize the particles in the center of the gas passage. These devices serve well for protecting the boiler walls, but can not be considered as suitable for slag prevention in large furnaces.

Even if some efficient means is developed for mixing the gas and excess air together, it is very questionable whether the slag difficulty will be entirely overcome. It is to be remembered that in addition the problem of sup-

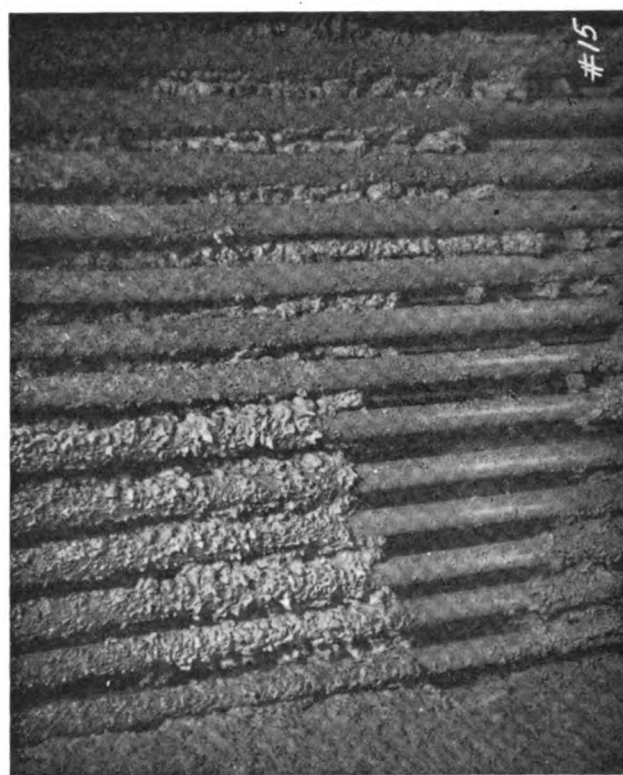


Fig. 5—Another typical illustration of serious slag formation on horizontal water tubes.

plying and mixing the oxygen and combustible gases, time is required for the various chemical reactions to take place.

There is but little chance for thoroughly mixing all gases in the combustion chamber, as the rapid rate with which the gases ascend prevent a thorough mixing and a stratification of the gases results. An illustration of this is shown on Chart I. These figures are values of CO_2 from gas samples taken under every second tube and at 2-foot intervals along the tubes vertically baffled.

These readings showed a carbon dioxide content of from 10.0 per cent along the walls to 17.5 per cent in the center. From these figures it can be appreciated that the chances for the ferrous material to change into the ferric state are very few. It was very evident that there was an insufficient penetrative effect from the ventilated walls

ANALYSES OF SAMPLES TAKEN FROM FIRST PASS BAFFLE OPENING IMMEDIATELY UNDER THE FIRST ROW OF TUBES

Tube No.	41	37	31	27	23	19	15	11	7	3
CO ₂	10.6	11.0	11.4	15.0	15.3	16.2	13.0	12.4	13.4	10.5
	10.1	12.0	14.0	16.0	17.5	13.4	13.0	12.8	12.8	13.0
	10.0	12.8	15.5	16.5	17.8	13.0	14.5	13.7	10.2	13.7
	11.9	10.5	14.9	15.7	17.9	14.3	14.0	14.3	13.4	10.6

to take care of the wide furnace, and also it is noted that there was considerable excess air along the walls.

Composition of the Slag on the Tubes and Furnace Walls.

Numerous samples of coal, ash, and slag were analyzed, the last of which are particularly interesting because they corroborate the above conclusions.

Table No. 3 gives a typical analysis of the slag taken from both the boiler tubes and the furnace walls.

TABLE 3—TYPICAL ANALYSES OF SLAG

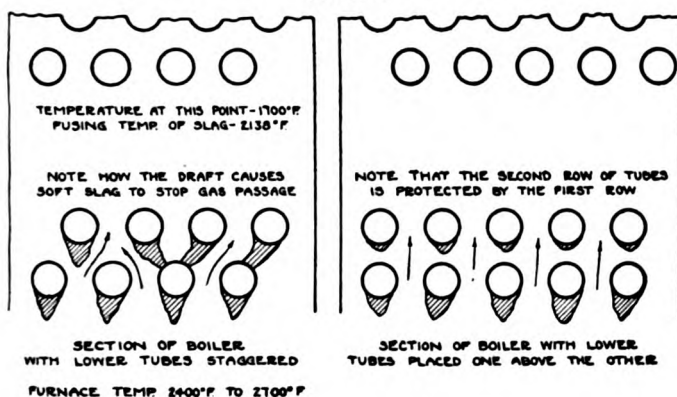
Sample of Slag Taken from Furnace Walls

Ferrous iron	8.26%
Ferrous iron calculated to ferric iron	9.18
Ferric iron, found as such	6.71
Total iron	15.89
Ratio of ferrous iron to total iron	57.7

Sample of Slag Taken from Boiler Tubes

Ferrous iron	3.23%
Ferrous iron, calculated to ferric iron	3.58
Ferric iron, found as such	8.21
Total iron	8.71
Ratio of ferrous iron to total iron	29.1

Chart I

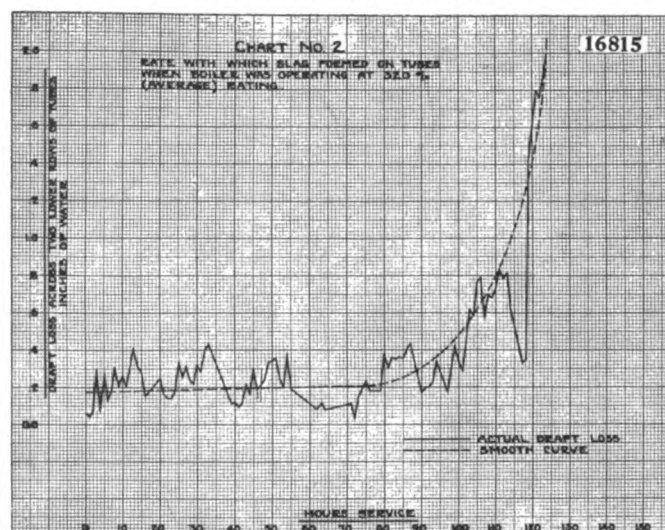


It is interesting to note that the slag on the furnace walls ran much higher in ferrous iron, by per cent, than did the slag on the tubes. In consequence of this the slag on the walls was much freer from the coarse friable infusible material than was the material on the tubes. The hard vitreous appearance of the slag on the walls gave evidence of having been there in a molten and flowing condition until such time as the furnace was cooled below the fusing temperature of the mass. The smooth appearance of the wall shown on Fig. 2 as compared with the rough material on the tubes, shown on Fig. 2, further verifies this point.

Numerous theories were advanced during this investigation as to the causes of slag formation on the tubes. Chief among these was the condensation of tarry vapors on the tubes to which the flying particles could adhere and solidify. It is true that the coal contained a high percentage of volatile matter and was rich in tars, but that this had a material effect in the formation of the slag is highly improbable. If tarry vapors existed in the ascending gases and actually condensed on the tubes

any coating on the tubes would be extremely thin. Tars are fairly good heat insulators and only a very thin coating of tar would form before it would begin to burn

Chart II—Showing rate of slag formation which is shown at end of test run in Fig. 1.



away when subjected to the furnace temperature, which at times was 2800 deg. F. to 3000 deg. F. Even if the lack of temperature permitted the film of tar to form on the clean external surface of the tubes, the insulating effect of a very thin layer of slag would prevent further condensation of tar. That this did occur was borne out by the fact that only about 1/16 in. to 1/8 in. of the slag on the tubes remained there in a completely frozen state. The melting point of the slag was 2138 deg. F., which is much above the vaporizing temperatures of any tars in the fuel and, consequently, a condensation of these tars would be impossible.

As commonly found in furnaces of all kinds, a considerable amount of visible solid particles were carried up with the rising gases. On the clean tubes these did not appear to have any effect, as they simply struck the tubes and rebounded, sometimes falling back in the furnace, or were carried through the boiler with the gases. Chart II is interesting in that it shows how rapidly the draft loss increased across the two lower rows of tubes, after an adhesive coating of molten slag had formed on the under sides of the tubes. After this coating had formed a great portion of the solid particles struck and adhered to the plastic material and the rapidity with which the slag formed was greatly increased, both by this and the rapidly growing area presented for contact.

On the large number of tests made it was indicated that the slag deposit on the tubes was nearly proportional to the total amount of gas, and was not greatly affected by the rating. The amount of slag was affected by temperatures in the furnace, however, for the hotter fires kept the slag in a more viscous state which greatly increased the tendency for cinders and particles of ash to adhere.

Experiments Made to Prevent Slag Accumulation.

As previously stated, the slag problem is a chemical one and the desirable remedy would be a chemical remedy, providing the cost of maintaining chemical action is not excessive. Such action may be set up in three different ways:

First—By feeding some material in with the coal that will act as an oxidizing agent.

Second—By feeding some vapor in with the air supply, which will dissociate and permit its oxygen to combine with the ferrous material present.

Third—By intimately mixing air, at high temperature, with the rising particles, so as to completely oxidize them before reaching the tubes.

By analysis of these three courses for experiments the first one was eliminated without trial. It was not considered feasible to feed any solid oxidizing substance in with the coal. The first cost would certainly be prohibitive, besides a greater amount of ash would have to be handled.

The second procedure was tried out by the injection of steam into the air supply. No decrease was noticed in the formation of slag on the tubes.

It is to be remembered that at no place in the fuel bed, except on the dumps, could the ash have been over 50 per cent of the total fuel bed. Further, the ferrous material was not over 10 per cent of the ash. It is, therefore, apparent that the ferrous material, representing a maximum of 5 per cent of the total fuel bed, had but little chance of coming in contact with the liberated oxygen and solidifying in its ferric state.

In reality this was expected, as it was deemed impracticable to put enough water through the fuel bed to insure complete oxidation of the ferrous material with all the other combustible matter present.

More recent experiments have shown that the introduction of water vapor into ash and refuse undoubtedly prevents a spongy mass of clinker from adhering together. This, however, is a vastly different proposition from the former, as it is necessary only to oxidize the surface to prevent adhesion where about 80 per cent of the material present is incombustible.

The third method suggested, namely by intimately mixing air with the gases, is now being tried. The original boilers were set about 13 feet from the grates. It was thought that, by increasing the distance between the grates and boiler tubes, the gases would have more opportunity to mix thoroughly. Also, since the total time of travel of the furnace gas is dependent upon the velocity and distance of gas travel, more time would be allowed for complete oxidation of the small particles. Consequently, a boiler was set up six feet higher than those originally installed.

Assuming that the rapidity with which the gas rises from the fuel bed is uniform, it is calculated that its velocity was about 18 feet per second. This is the lowest possible velocity that can be expected. The direction of gas travel is from the grate direct to the baffle opening, which was proportioned as 46 per cent of the grate surface. Necessarily the velocity was twice as high under the baffle as it was leaving the fuel bed.

On this basis, the time it took for particles to reach the tubes with the original installation would be $13 \text{ ft.} \div 18 \text{ ft.} = .72 \text{ sec.}$ This is very little time for oxidation to take place, unless it is of an explosive character. Further, by raising the boiler to 19 ft. this same time would be $19 \text{ ft.} \div 18 \text{ ft.} = 1.05 \text{ sec.}$, which is still of very short duration.

This arrangement has not shown any great improvement in slag prevention and has the disadvantage of exposing more brickwork to high temperatures and to draft with resulting greater infiltration of air through the setting.

Furnace construction undoubtedly has much to do with the external encrustation of the tubes with slag. The ratio of the exposed tube surface to the grate area

was 1 to 1. This is very low and the lower the ratio, under set conditions of fuel and fuel bed, the higher will be the furnace temperature. It is apparent that the higher the furnace temperature the greater will be the tendency for the ash to fuse and stick.

It has become common practice now to have the ratio of exposed tube surface to grate surface as high as 1.87 to 1, and is seldom less than 1.2 to 1. By increasing this ratio the amount of heat radiated up and absorbed is very materially increased with a consequent reduction in furnace temperature.

This last item, namely furnace construction, is a step in the right direction. Unfortunately, the construction of the investigated installation did not permit changing the ratio (1 to 1), and, for comparative purposes, it was necessary to refer to a neighboring station with a similar type of stoker and boiler, and which used a similar coal. This second plant has had practically no trouble with slag on tubes and uses only the soot blowers while the boilers are in operation.

An interesting difference in the two stations was that the first two rows of tubes in the former were staggered, and slag impinged on and stuck to both rows. The second row caused more trouble than the first row, as the slag took the form of icicles or stalactites and when they became long enough and the velocity of the gas became high enough, the "icicles" bent sideward until they touched the lower tubes. This effectively sealed the gas passage of that part of the boiler. (See Chart III.)

The second installation had the first two rows set one above the other. The material which struck the bottom row of tubes adhered, but the rapidity of the formation was far less. On account of this arrangement, the gases were sufficiently cooled by passing between these tubes to prevent the slag from sticking and there was no further tendency for the slag to adhere to the boiler surfaces.

When it is considered that the ash is very finely divided in the coal, and that some of it is certain to be carried up with the gas, it appears that the most fruitful field for development of means for slag prevention is in furnace and boiler design. This belief has already been justified. At the same time there is still need for further development of apparatus for mechanically removing soot and slag from boiler tubes.

From the foregoing it is seen that the chemical composition and fusing temperatures of the ash were known, and a careful and complete record was obtained of all happenings in the furnace and around the boiler. With the aid of this information and the assistance of the United States Bureau of Mines, evidence was obtained that has led to the above general conclusions.

Considerable value was received from this investigation because much was learned of the effect of furnace, boiler and stoker construction on the slag problem.

It is extremely fortunate that only a comparatively few coals give slag trouble to a serious degree. A great many coals have fusing temperatures so high that they give no trouble with ordinary furnace temperatures. Another class of coals have low fusing temperatures, but do not seem to have the tendency to be lifted from the fuel bed. But when a coal gives serious slag trouble, with the present knowledge of the art of burning coal, means must be provided for its mechanical removal. This, however, is not as serious a matter as it appears, for soot blowing in boiler plants is now recognized as a necessity, and apparatus for soot removal is now installed as a regular boiler equipment.

Boiler Feed Water—As it Ought to Be—Zero Soft

Continuous Uninterrupted Power Demand by Steel Mills—Boiler Scale Costly and Unnecessary—Commercial Synthetic Zeolites.

By ERNEST ROWE*

SO heavy and continuous is the duty demanded of the power plant in the blast furnace and steel mill, so high is the ratio of the power factor to total value added by the processes of the industry, that its operation, both from the mechanical and cost standpoints, is highly sensitive to conditions, good or bad, which affect the production of power or the cost of its production. In a silk mill or an oil refinery the loss involved from the ordinary troubles with the power plant appear in the value of the finished product as an infinitesimal fraction. But in the steel mill the influence of unrestricted power supply is immediately felt throughout the production sequence, with an effect so cumulative that costs and selling prices are seriously affected.

Boiler scale is one of the most serious troubles encountered by the average blast furnace or steel plant, and the reason is not far to seek. Not enough intelligent interest is shown in the matter.

The water supply, from which most furnace and steel plants in this country derive their boiler-feed, is anything but ideal, often high in free acid, usually bicarbonate, and always heavy with incrusting solids. From the very nature of the operation, most boiler houses are small and scattered, not particularly well designed, and poorly operated. Many of the steel plant mill engines, especially the older ones, operate non-condensing, a large percentage of those condensing use jet condensers and no attempt whatever is made to recover condensate. The result is of course practically 100 per cent raw "make-up" for boiler feed with bad scale, forming raw water badly treated, scale and heavy scale is inevitable.

Probably it would take an incalculable figure to express the power losses and power production inflicted by boiler scale in fuel consumption, deficient evaporation, tube replacements and other repairs, cleaning, spare equipment, to allow for idleness during cleaning, extra labor, and so on.

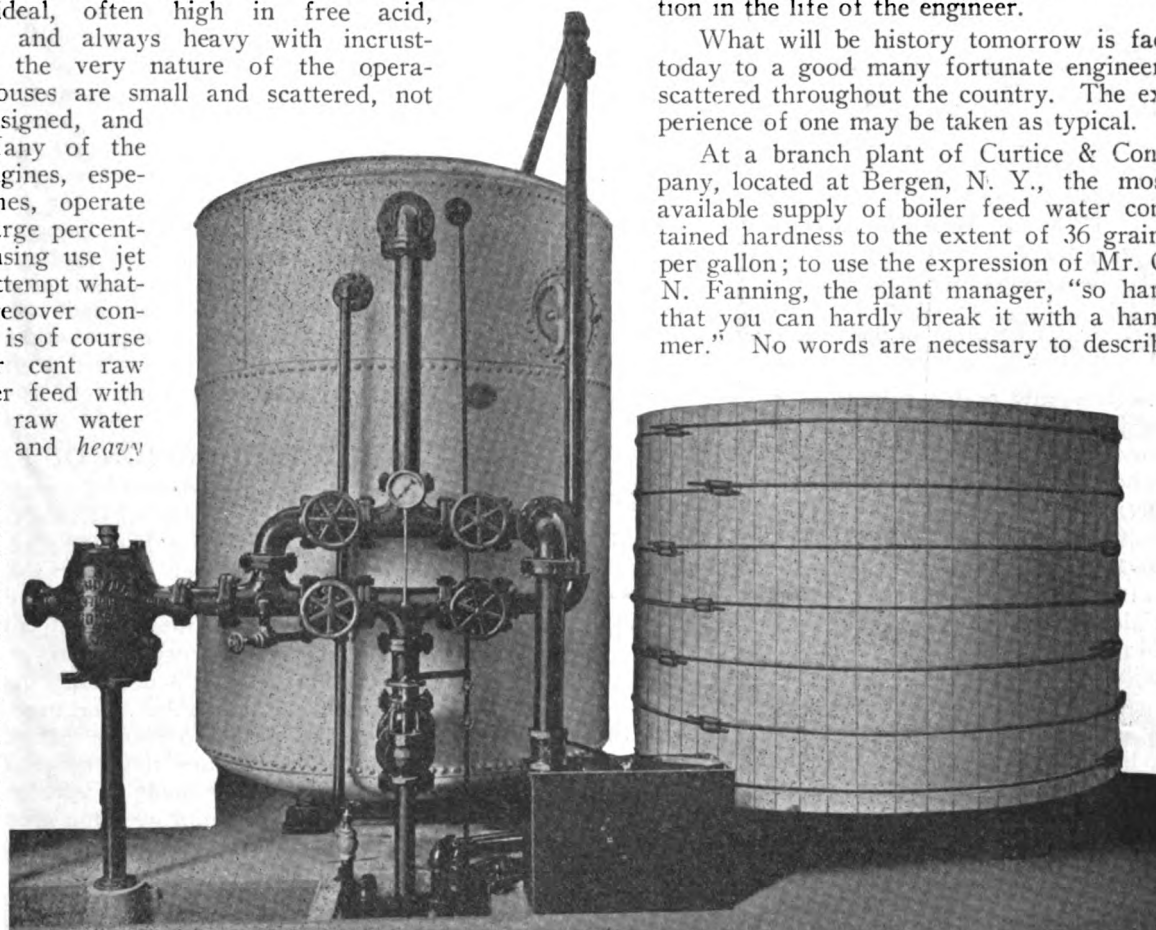
Modern methods have removed

the reasons for any toleration of scale formation. Softening water has become a successful art, which places a heavy burden of proof upon the plant which still has recourse to the "hand removal by mechanical cleaner method" of wasteful accumulation of scale. Without quibbling, such a plant is out of date in its methods.

Anyone who challenges the assertion that boiler scale is entirely unnecessary, and can definitely be eliminated, merely acknowledges that he has failed to keep pace with the progress of science, as applied to water purification. There is no longer any more excuse for the presence of scale in a boiler or feed water heater today than there would be for the presence, in the engine room, of the boy who in the early days was employed to jerk the slide valve with a string. That ended when one day a lazy boy hitched the string to the flywheel; the eccentric rod resulted and the boy and his job were forever eliminated. The valve boy is a curiosity today. Boiler scale will be or should be a curiosity tomorrow, something for the historian to write about, but no longer a question in the life of the engineer.

What will be history tomorrow is fact today to a good many fortunate engineers scattered throughout the country. The experience of one may be taken as typical.

At a branch plant of Curtice & Company, located at Bergen, N. Y., the most available supply of boiler feed water contained hardness to the extent of 36 grains per gallon; to use the expression of Mr. C. N. Fanning, the plant manager, "so hard that you can hardly break it with a hammer." No words are necessary to describe



Permutit zeolite water softening system. Showing by-pass valve arrangement and storage tank for zero water.

*Consulting Engr.

the difficulties of making steam with such raw water. Boilers, heater, piping, valves, pumps and pump-valves, every point in contact with the hot boiler feed was subject to incrustation.

Evaporation results were exactly on a par with the before mentioned conditions, the amount of coal fired was out of all proportion to the steam generated and work done. Although these boilers were in service but a short season during the year, they invariably required retubing annually.

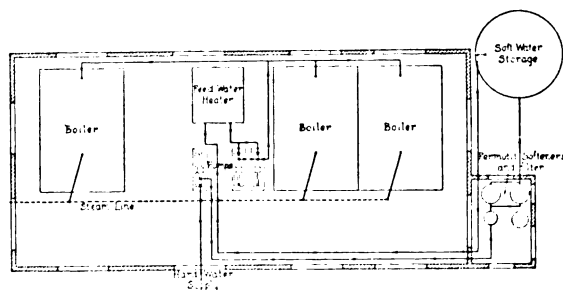
Three years ago a Permutit zeolite water softener, as auxiliary to the feed water system, was installed; since that time all troubles due to boiler water have disappeared, and in three years of operation the boilers have required absolutely no repairs. Recently they were opened for inspection and, in the opinion of Mr Fanning, the boilers could have looked no better if they were new; there was not the slightest evidence of scale.

Incidentally the plant records indicate a saving in coal alone equal to the cost of the Permutit softener.

Zeolites used in water softening are a tri-basic compound, sodium-aluminum-silicate.

Natural zeolites of commercial value for this purpose are found in widely scattered deposits. In general they lack the uniformity and dependability of the manufactured article; synthetic zeolites can be and are made for a great variety of definite purposes.

The essential value of this remarkable product is the unique attribute which it possesses of "exchanging bases," calcium and magnesium for sodium; and, alternately, sodium for calcium and magnesium.



Layout of water softening plant.

Any raw water containing calcium or magnesium, which form the so-called "hardness" in waters, when brought into contact, by filtration or percolation through a bed of zeolite, will be found to have lost all that "hardness," the sodium of the zeolite, which is soluble and non-incrusting, will have taken the place of the calcium and magnesium.

The zeolite in the filter-bed will have become
 Calcium }
 Magnesium } Aluminum, Silicate and the effluent water
 will be zero soft.

The reverse operation restores the zeolite to its original condition. Sodium, in dilute solution, the ordinary salt of commerce being employed, serves as the re-exchange medium.

The operation of "regeneration," as this re-exchange of base is termed, is entirely mechanical, simplicity itself. No chemicals whatever are used, the time element may be made unimportant, and the results are positive. Very slight loss of zeolite material occurs—that incident to a flushing operation only—and the life of the material seems to be indefinite.

Permutit zeolite water softening plants are in continuous operation under every variety of conditions from the Atlantic to the Pacific. Many installations are giving ideal results where all other methods failed and failed badly. There are no limitations as to size of softening plant, and no limitations as to the daily volume of water which such a plant may be designed and built to handle.

Reference was made in the first paragraph of this article to the power losses and the excessive cost of power production inflicted by boiler scale. Serious as those direct effects are, they do not constitute all, nor indeed the worst, of the waste caused by raw hard water. The decided trend toward larger boiler units, a development which is particularly important in the blast furnace and steel mill industry with its large power units, has magnified these difficulties. One of the reasons for a battery of boilers rather than a single boiler of capacity equal to the aggregate of the battery has been that it was necessary to shut them down, one after another, for cleaning. So long as scale was a "necessary evil," continuity of operation was maintained at the cost of a certain degree of cumbersomeness, appreciable inefficiency and excessive space. It is now possible and economical to eliminate this. With a constantly clean surface on the water side of the metal, with the insulating coat of scale gone, never to return, affording uninterrupted conduction of heat from fire to water, there is never any overheating of the metal, either in tubes or shell, consequently no loss of tubes or drums.

Zero water also does away with foaming. This in turn permits, in most installations, of minor alterations in equipment and operation which further improve duty, as foaming or priming carry in their wake a whole train of undesirable penalties.

The result of all this is that it is nothing unusual for a boiler on zero water to operate at 200 and even 300 per cent of its rated capacity. Boilers are doing that today which previously were unable to deliver 100 per cent of their rating except for a few days immediately after thorough cleaning. The value of this margin of power, gained without the necessity of additional investment in boilers and housing, is obvious. That it does not unduly overload a well made boiler is shown by the strikingly unanimous reports that the need of repairs ceases when the boiler is fed with the kind of water it ought to have, zero water.

THE PRODUCTION OF RUSTLESS IRON

There has been developed recently in England a "rustless iron." This material is iron to which a certain proportion of chromium has been added. A similar alloy called "stainless steel" has for some time been familiar to metallurgists. Stainless steel differs from rustless iron chiefly in that it contains small amounts of carbon. In order to produce rustless iron, an iron-chromium alloy free from carbon, it is necessary that carbon-free iron and chromium be available. The usual forms of chromium, commercial grades of ferro chromium, contain comparatively large amounts of carbon. The discovery of rustless iron has thus made it very important to be able to treat ferro-chromium by some process which will remove the carbon. Among the methods proposed is that of heating ferro-chromium in contact with hydrogen.

This work is described in Scientific Paper No. 448 of the Bureau of Standards, available from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5c per copy.

WITH THE EQUIPMENT MANUFACTURERS

MOTORBLOC—THE MOTOR DRIVEN CHAIN HOIST

An electrically operated material-handling device, known as the Motorbloc, has been placed on the market by the Motorbloc Corporation of Summerdale, Philadelphia. This

new device has been developed to serve the operations lying between the well-defined field of the standard hand chain hoist and that of the traveling electric hoist.

The Motorbloc is a rugged, and readily portable hoist, which can be installed with the facility of an electric drill, and the self-contained pendant controller permits convenient operation as soon as the cord has been plugged into the nearest electric circuit.

Great care has been used in avoiding the stressing of the hoisting mechanism beyond the loads and speeds for which it is proportioned for hand operation.

It consists of a standardized chain hoist of steel construction, electrified by the application of a specially designed heavy-duty motor, liberally pro-

portioned reduction gearing and slip friction clutch, applied by means of a malleable iron supporting bracket comprising a self-contained electrifying unit, to which the pendant controller is also attached. In this way a simple, rugged mechanism has been developed for the electrification of the standard spur-gear chain hoist in capacities ranging from $\frac{1}{4}$ to 10 tons, proportioned to stand up under the severe overloads and abuse to which portable apparatus of this character is subjected by common labor, generally unfamiliar with the handling of power machinery.

Extreme care has been given to features of compactness, symmetry and balance, combined with lightness and strength through the use of the highest grade materials, liberally proportioned to meet the most severe service conditions. The armature shaft and worm are carried in heavy duty ball-bearings and liberal provision has been made for adequate, automatic lubrication.

The self-contained, pendant controller is easily operated by the fingers of one hand, leaving the other hand free to guide the load. This arrangement makes it possible for one man, without physical effort, to accomplish what would otherwise require two or more men for lifting and placing the same load. The ready portability of the unit is apparent from the fact that the one-ton size complete weighs only 148 pounds.

The extreme simplicity of this mechanism is promoted and the operation safeguarded by the use of the ring-oiled slip friction clutch which prevents damage from over-running to the hoist parts and chain and at the same time completely protects the motor from overload, without the complication of an electric limit switch.

For occasional use at points where electric current is not available, or in the event of the temporary failure of electric power, the hand chain can be quickly applied, and the hoist operated as an ordinary block.



THE NEW HAUCK OIL BURNER

The Hauck Venturi Fuel Oil Burner is a new and improved type of atomizer in which oil or even tar is completely atomized or broken up into finely divided fog-like particles by means of steam or compressed air.

The burner consists essentially of a cylindrical casing with slots parallel to the bore axis. These slots form with the inner wall of the casing longitudinal ports or orifices through which the atomized oil is impelled into the furnace. Each port or orifice is a small Venturi tube constricted at its center and flared outwardly at the two ends. The throats or constricted parts of the orifices are connected with the interior of the bore by means of radial openings or apertures.

The oil or tar is delivered under a pressure of 40 to 60 lbs. per sq. in. to the bore, and then passed through the radial apertures to the orifices where it is collided against and blasted by the compressed air or steam.

The compressed air or steam is delivered to the burner at about 80 to 100 lbs. per sq. in. pressure. As it flows through the ports, its velocity increases rapidly and becomes a maximum at the orifice throats. Here it strikes and blasts the oil, atomizes it thoroughly, even by-product tar, and impels the atomized oil from the burner.

The Hauck Venturi Oil Burner secures a thorough mixture of the air and atomized fuel oil at the mouth of the burner. It is correctly proportioned to the oil and steam or air pressures available, is accessible for purposes of cleaning and inspection, and can be conveniently removed from the furnace without affecting the operation of any other burner served by the same piping system.

Reducing, neutral and oxidizing flames are readily obtained merely by manipulating the oil and air valves. The furnace atmosphere is thus closely controlled.

Combustion can be made to take place close to the burner nozzle. Oxygen consequently cannot come into contact with the steel. This results in less scaling. Decarburizing of the work is reduced, and there is less spoilage and greater uniformity of product.

Close control of temperature is accomplished with ease and certainty. The temperature of the furnace is controlled through two standard valves. The labor and attention required are a minimum.

Uniform combustion conditions and ready, exact and simple temperature control increase the efficiency of production. Fewer demands are made upon skill and judgment in the handling of the furnace, and more time and attention can be devoted to the work itself.

The Hauck Venturi Oil Burner is simple to install and easy to operate. The efficiency of the burner is high. It is adaptable to a wide range of work, including the following:

Baking, bolt heading, bluing, carburizing or case-hardening, continuous reheating, core ovens, drying, enameling, forging, galvanizing, hardening, japanning, ladle drying, lead and cyanide pot furnaces, melting furnaces with crucibles, melting furnaces without crucibles, muffle and retort furnaces, non-ferrous and precious metal melting, oil tempering baths, open hearth furnaces, plate, angle and rod heating; rivet forges, scrap reclaiming, soaking pits, soft metal melting, tinning wire, strip and sheet, tool dressing, tube brazing, vitreous enamel melting, welding.

NEWS OF THE PLANTS

Power Specialty Company, builders of Foster superheaters, economizers and oil heating and cooling equipment, announces the opening of new branch offices. Mr. L. Lanyi is to be in charge of the office at Dime Savings Bank Building, Detroit, Mich., and Mr. R. B. Nutting, who was formerly Chicago district manager, in charge of office at 2324 Fourteenth Street, Boulder, Colo.

The Guilbert Steel Company, Diamond Bank Building, Pittsburgh, Pa., recently organized under state laws, has acquired property in the West Park district for the construction of a new plant for the manufacture of steel products including a general fabricating works. Plans will be prepared at once for the initial buildings, to comprise a main one-story structure, 50x200 feet, to cost approximately \$100,000, with machinery. The new company is headed by O. E. Guilbert and R. C. Stewart. It is represented by John Reberman, Jr., 43 Nicholas Building, Pittsburgh.

George M. Thompson, West Newton, Mass., formerly vice president and general manager of the Wickwire Spencer Steel Corporation, Worcester, Mass., is organizing a new company to manufacture a line of steel products and operate a rolling mill. Plans have been prepared for the construction of the proposed plant on site at 41 Mildred Avenue, Dorchester, Mass. The rolling mill will be 60x115 feet, and supplemented by two other structures 50x150 feet and 25x35 feet, each one-story. It is proposed to have the plant ready for service at an early date. Brainard, Leeds & Kellogg, 89 Franklin Street, Boston, Mass., are architects.

The Southern Sheet Steel Company, Chattanooga, Tenn., recently organized, has plans in progress for the construction of a new local plant, designed to manufacture sheet steel, 12-gauge and smaller. The initial works will consist of an eight-sheet rolling mill and three open-hearth furnaces, each with capacity of about 60 tons. It is expected to give employment to a working force of about 700 men when operating at capacity, with estimated output of close to 55,000 tons per annum. The entire works will cost in excess of \$1,200,000, with machinery. W. M. Bleckner is president; and W. J. Lynch, vice president in charge of operations. Equipment purchases will be made at an early date under the direction of the last noted official.

The American Rolling Mill Company, Middletown, Ohio, has plans nearing completion and will soon break ground for the construction of additions to its plant at Ashland, Ky., to provide for a complete system of blast and open hearth furnaces, blooming mill, sheet and finishing mill and miscellaneous structures for the production of general commercial steel products. The new structures will consist of a one-story sheet mill, one-story jobbing mill, and one-story galvanizing plant, estimated to cost approximately \$250,000, with machinery. Dwight P. Robinson & Company, Inc., 152 East Forty-sixth Street, New York, N. Y., is engineer and contractor in charge.

The Bethlehem Steel Corporation, Bethlehem, Pa., has plans in progress for extensions and improvements at its Lackawanna Steel Works, Buffalo, N. Y., recently acquired, and will arrange a fund of about \$15,000,000 for the expansion. The plant will be remodeled and modernized and considerable new machinery installed in the different operating departments. The capacity

will be considerably increased. The company is advancing production at its Bethlehem works as well as at its plant at Steelton, near Harrisburg, Pa. A number of operating units at the last noted plant have been placed in service after an inactivity of more than a year.

The Empire Drawn Steel Company, 1133 Marine Bank Building, Buffalo, N. Y., is completing plans for the construction of a new local plant on Germania Street, for the manufacture of cold drawn steel products, and other steel specialties. The main structure will be one-story, 75x450 feet, and is to be equipped for an initial output of approximately 35,000 tons per annum. It is estimated to cost upwards of \$100,000. Work will be placed under way at an early date.

The New Process Steel Company, Noblesville, Ind., is completing the construction of the initial units at its new local plant, and will commence immediate production at a portion of the works. The company will specialize in the manufacture of steel billets, small-sized T-rails, and structural steel shapes. The entire works is expected to be ready for service early in the coming year, and production will be advanced at that time to include a working force of more than 2,000 men, on a full-time working basis. J. F. Reiner is president of the company; J. E. Owen, vice president, and James Hundley general manager.

The National Enamel & Stamping Company, 411 Fifth Avenue, New York, N. Y., has foundation work in progress for the new sheet mill at its plant at Granite City, Ill. Plans for the superstructure have been completed, and it is proposed to push the erection to consummation at the earliest date. It is estimated to cost approximately \$1,000,000, including machinery.

The Andrews Wire & Iron Works, 1802 Preston Street, Rockford, Ill., manufacturers of steel and iron products, has plans in progress for the construction of a new plant addition for general increase in capacity, to be one-story, and estimated to cost approximately \$50,000. Peterson & Johnson, 406 S. A. Bank Building, Rockford, are architects.

The Columbia Steel Company, Elyria, Ohio, has been re-organized and succeeded by a new company of the same name, formed under state laws, with a capital of \$1,500,000. Plans are under way for a number of improvements in the works, to include the installation of perfected processes of manufacture, and considerable new equipment for projected expansion. To provide for the work a preferred stock issue of \$500,000 is being arranged. C. E. Lozier, heretofore vice president and general manager of the company, has been elected chairman of the board; H. M. Naugle is president; K. R. Jensen, secretary and treasurer; and A. J. Townsend, vice president, in charge of operations.

The Lukens Steel Company, Coatesville, Pa., manufacturers of steel plate, etc., have acquired property on the Industrial Canal at New Orleans, La., as a site for a new branch plant. Preliminary plans are under way for a complete fabricating works to consist of four units, 75x250 feet, estimated to cost approximately \$300,000. A large warehouse building will also be built for immediate service.



Carl G. Schluederberg, assistant to the managers of the Supply and Merchandising Departments of the Westinghouse Electric & Manufacturing Company and special representative of that company in foreign countries, left recently for a four months' trip in the Orient to study business conditions there. Mr. Schluederberg will visit Japan, the Philippines and China to make a sales survey, investigating especially the possibilities of expansion of the market for household appliances. Mr. Schluederberg is well known in American electro-chemical circles and has held various important offices in the American Electro-Chemical Society. He graduated from the School of Electrical Engineering of Cornell University in 1902, and in that year entered the employ of the Westinghouse Electric & Manufacturing Company. In 1905 he took up research work along electro-chemical lines and also entered upon postgraduate work at Cornell University, which he continued until 1908, when he was awarded the degree of Doctor of Philosophy and a degree in chemistry. He also spent some time abroad on special investigations and subsequently became associated with the Carnegie Steel Company and later the United Coal Company in metallurgical and electrical engineering work.

M. W. Hall, chief mechanical engineer, South Side Works, Jones & Laughlin Steel Company, Pittsburgh, recently resigned and has been succeeded by C. G. Bigelow, formerly with the American Sheet & Tin Plate Company.

Harry W. Coffin, vice president and general manager, Alabama Company, Birmingham, Ala., retired, effective November 15. John W. Porter, vice president and sales manager, who has been with the Alabama Company for 14 years, will assume Mr. Coffin's duties in addition to his own.

Harry J. Cogswell, formerly associated with the Ajax Forge Company, Chicago, recently joined the organization of the Valley Forge Steel & Tool Company, Chicago, as general sales manager.

Joseph G. Shryock, designing engineer, Belmont Iron Works, Philadelphia, Pa., has been appointed chief engineer of that company.

W. W. Heylman, formerly chief chemist of the St. Louis Coke & Chemical Company, Granite City, Ill., has been appointed

blast furnace superintendent, succeeding T. W. Harris, who resigned recently to become connected with the Tata Iron & Steel Company of India.

Fred C. Severin and B. H. Tripp have formed a partnership for the purpose of buying and selling used machine tools. They have taken an office at 25 Church Street, New York. Mr. Severin was for many years with the Niles-Bement-Pond Company and more recently with the Betts Machine Company, Rochester, N. Y., now a part of the Consolidated Machine Tool Corporation, and Mr. Tripp was for many years connected with the Chicago Pneumatic Tool Company.

R. L. Bears, who has just been appointed chief engineer of the Detroit Stoker Company, graduated from Syracuse University in the 1912 class in Mechanical Engineering. Leaving the university, he spent four years with the United States Bureau of Mines under Mr. O. P. Hood, doing research and testing work on various fuels and combustion apparatus. Four years ago he was appointed testing engineer of the Underfeed Stoker Company of America and was later promoted to the position of assistant chief engineer.

F. F. Rohrer, assistant to manager of both the Power and Railway Departments of the Westinghouse Electric & Manufacturing Company, has been appointed general contract manager of that company. In his new appointment, which is effective immediately, Mr. Rohrer will be a member of the staff of W. S. Rugg, general sales manager.

W. W. Sayers, of the Link Belt Company, has been appointed chief engineer of the Company's Philadelphia Works and eastern operations. Mr. Sayers was representative of the company in their Chicago territory in the lines related to power house machinery, coal storage, Peck carriers, crushers, etc., and later in charge of the Locomotive Crane Department.

John K. Boll, for many years sales manager, Page Steel & Wire Company, has resigned to accept an important position with the Wheeling Steel Products Company, which will sell the output of the new rod and wire mills of the Whitaker Glessner Company, now nearing completion at Portsmouth, Ohio. Mr. Boll assumed his new duties November 16.



William H. Blount, superintendent Sleeper & Hartley, Inc., Worcester, Mass., wire drawing machinery, has resigned for the purpose of devoting his entire attention to the affairs of the Arey & Blount Electric Company, recently organized to manufacture electric flashlights.

H. B. Bole resigned as first vice president of the Hydraulic Steel Company, Cleveland, Ohio, at the annual meeting on October 27. He will remain as a member of the board of directors.

B. F. Phillopon, president Climax Molybdenum Company, 61 Broadway, New York, sailed on the Majestic on October 29 for France, where he will spend four or five weeks on business.

G. Ernest Wells, director Edgar Allen & Company, Ltd., Sheffield, Eng., is in the United States visiting the western and eastern offices of the Edgar Allen Steel Company, Inc., 86 John Street, New York.

Wm. H. Warren, formerly general manager of Brier Hill Steel Company, Youngstown, Ohio, and previously with the Gary Works of the United States Steel Corporation, has been appointed general manager of the Trumbull Steel Company, Warren, Ohio.

Charles E. Beeson, who on November 1 was elected a vice president of the Pittsburgh Steel Company, has been identified with that company since its organization in 1901, having been its first secretary and holding that office until about two years ago. For the past three years Mr. Beeson has been a director and a member of the executive committee.

Stephen Badlam has been appointed works manager of the Superior Steel Corporation, Pittsburgh, the plant of which is at Carnegie, Pa., succeeding James Warren, who resigned recently to become works manager of the LaLance & Grosjean Mfg. Company, Woodhaven L. I. For the past year Mr. Badlam has been engaged as an engineer specializing in rolling mill equipment in Philadelphia, but previously for 12 years had been in the operating department of the Pennsylvania Steel Company; served as assistant chief engineer, Pittsburgh Crucible Steel Company during the building of its plant at Midland, Pa., and later was chief engineer, Pittsburgh Seamless Tube Company, Beaver Falls, Pa. In the World War, he was major of

infantry on the general staff, First Army, and was overseas for two years. Following the war he was sales engineer with the Philadelphia Roll & Machine Company. He is a graduate of Massachusetts Institute of Technology.

Willis L. King, vice president, Jones & Laughlin Steel Company, Pittsburgh, has returned to his desk after an absence of several weeks due to illness, which also prevented his attendance at the recent meeting of the American Iron and Steel Institute, of which he is a vice president. Mr. King on July 12 last rounded out 53 years with the Jones & Laughlin Steel Company.

P. D. Brown has been appointed district sales manager in southern territory of the Polidi Steel Corporation of America, with headquarters at Baltimore. Mr. Brown was formerly general manager of the Lakeside Forge Company, Erie, Pa.

C. V. Dodge, formerly in charge of steel casting sales for the United Engineering & Foundry Company, Pittsburgh, has been promoted to assistant manager in charge of roll and steel sales. He began his career with the company in 1904 as shipping clerk at the steel foundry in Vandergrift, Pa., and was later made foreman of the chipping shop at this plant. In 1916, he was given charge of steel casting sales.

John Duncan, president Illinois Company, St. Louis, Mo., and formerly president of the Wheeling Steel & Iron Company, has been elected a director of the National Enameling & Stamping Company.

J. J. Stoddard has been appointed general manager of the Lakeside Forge Company, Erie, Pa., manufacturers of drop forged wrenches and forgings. Since the first of the year he has held the position of sales manager.

A. H. Hunter of Buffalo has resigned as president of the Atlas Steel Corporation, Dunkirk, N. Y., a consolidation of the Atlas Crucible Steel Company of Dunkirk and the Electric Alloy Steel Company, Youngstown, Ohio. Mr. Hunter was formerly president of the Atlas Crucible Company. The position will remain vacant and the duties of president will be performed by L. J. Campbell chairman of the board in immediate charge of the company. Mr. Campbell was previously president of the Electric Alloy Company.

Some Pointers on By-Product Coke Oven Operations

COMBUSTIBILITY OF COKE

Further work on the combustibility of coke and relative re-activity with carbon dioxide is being conducted by the southern experiment station of the United States Bureau of Mines, Birmingham-Tuscaloosa, Ala., in co-operation with the Pittsburgh, Pa., station of the bureau. Two variable properties of coke, namely, its combustibility and rate of oxidation of "solution" in carbon dioxide, are believed to play an important part in its performance in the blast furnace. It has been stated that the ideal coke should come down to the tuyere zone without oxidation by the carbon dioxide in the stack gases (Gruner's ideal working) and should there burn rapidly to carbon monoxide. Laboratory scale tests for determining relative combustibility of cokes and their reactivity with carbon dioxide have been developed and a number of by-product and beehive cokes tested. The relation between these values and the physical properties of the coke has been studied. A comparison of laboratory scale test results and results of actual furnace practice is being made.

DETERMINES ASH IN COAL WITH MILK TESTER

A. M. Rogers, a research worker in the School of Mines at the Pennsylvania State College, has devised a novel scheme for estimating rapidly the percentage of ash likely to be contained in a given sample of coal. By means of a centrifuge such as is used to test the proportion of cream in a given sample of milk, he has succeeded in making tests of coal in a few minutes whereas the previous method, which necessitated the burning of the coal, took nearly a day.

The coal to be tested is ground finely and poured into test tubes containing a liquid. When the tubes are whirled around rapidly by the centrifuge, the slate and sulphur go to the end of the tube and the combustible part of the coal is left near the top. Graduations, like those used in the milk and cream tester, show at once the proportion of waste in the coal.

TO CLOSE GAP IN BY-PRODUCT COKE STATISTICS

The U. S. Geological Survey has recently been getting a monthly report of by-product coke output corresponding to the reports received during the war. However, figures have not been available for 1919 and 1920 and the survey is now planning to get these data so that there will be a continuity of record from 1917 on.

The survey is urging co-operation of the industry in this matter. It is recognized that the data are of very great industrial significance not only in the coke industry itself but also to metallurgical industries and fuel users generally. An early summary of the data is promised if prompt reply is received by the survey.

TESTING MATERIALS SOCIETY DEFINES COKE*

In order to standardize the methods of testing coke and to give it a nomenclature which will be of nation-wide acceptance, the Society for Testing Materials, in its annual volume of tentative standards, has included a chapter entitled "Tentative Definitions of Terms Relating to Coke." It de-

fines coke, beehive coke, by-product coke and gashouse coke.

Foundry coke from beehive ovens it designates as coke which is physically and chemically suitable for use in foundry cupola practice. It may be either 72 or 48-hour coke. The principal difference between the two is the greater size of the 72-hour coke, due to thicker coal beds employed in its preparation. The breeze, or fine coke—smaller than approximately $\frac{3}{4}$ -in.—is forked or screened out.

Foundry coke from by-product ovens is coke that is physically suitable for foundry cupola practice and which passes over a screening device having approximately $2\frac{1}{2}$ in. openings. It is not produced in any standard coking time.

Furnace coke from beehive ovens is coke that is physically and chemically suitable for the reduction of iron ore in blast furnaces. The breeze smaller than approximately $\frac{3}{4}$ -in., as in foundry coke from the same source, is forked or screened out. The usual coking time is four 48-hour charges and two 72-hour charges.

Furnace coke from by-product ovens is coke that is physically and chemically suitable for the reduction of iron ore in blast furnaces and which passes over a screening device with openings varying from $\frac{3}{4}$ in. to $1\frac{1}{2}$ in., depending on local conditions at different plants. It is not produced in any standard coking time.

Domestic coke is coke of the smaller screened sizes, below approximately $2\frac{1}{2}$ in., suitable for use in domestic stoves, heaters, etc. The standard sizes are quite generally sold under the names given in the table and the screened sizes are average, although locally varied somewhat.

USUAL SIZES OF DOMESTIC COKE

Name	Size of Screen	
	Passing	Retained
Egg	$2\frac{1}{2}$ In.	$1\frac{3}{4}$ In.
Stove	$1\frac{3}{4}$ "	$1\frac{1}{4}$ "
Nut	$1\frac{1}{4}$ "	$\frac{3}{4}$ "
Pea	$\frac{3}{4}$ "	$\frac{1}{2}$ "
Breeze	$\frac{1}{2}$ "	..

The chapter also defines for purposes of analysis dry coke, moisture, ash, volatile matter and fixed carbon. Volatile matter is described as that part of coal or coke which on heating is driven off in the form of tars and gases and is determined as the percentage loss in weight, less the percentage of moisture, sustained on heating coke in a covered platinum crucible for seven minutes at a temperature of 950 deg. C.

Obviously coal should be omitted in the first part of this definition if it is not to be placed in the last part. Certainly all the volatile matter driven off dry coal does not consist of tars and gases unless steam is regarded as a gas, which indeed it is, but it would seem that the words were put in purposely to exclude steam, for if it does not exclude it these words are entirely useless. The definition is faulty and misleading.

Dry coke is defined as coke which has been dried to constant weight at temperatures not less than 104 deg. C. nor more than 200 deg. C. in the case of lump coal and between 104 deg. C. and 110 deg. C. in the case of 60-mesh coke. This also is not as specific as it with advantages might be made. Why leave a range as great as that between 104 and 200 deg. C.?

*From Coal Age, November 23.

TRADE PUBLICATIONS

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Steel Conveyors — Sandvik Steel, Inc., 233 Broadway, N. Y., has issued Catalog No. 18 which contains information on the application of the steel belt in conveying problems, also as to its efficiency and economy. Illustrations are supplemented with fractional views of various units in the construction. The booklet contains 2 pages.

Alloy Steels — The Central Steel Company, Massillon, Ohio, has issued a 44-page booklet giving a brief story of the evolution of the alloy steel industry, and listing many parts for which alloy steels are used. Numerous charts are included giving chemical and physical characteristics of many most generally used alloy steels. Specifications are also given of some of the special alloy steels made by this company.

Combustion Device — Crown Fuel Saver Company, Richmond, Ind., recently issued an illustrated circular describing a device for introducing supplementary air for combustion immediately above the fuel bed of coal-burning furnaces. Earl F. Whitaker, 30 Church Street, New York, is agent.

The **Century Electric Company**, St. Louis, Mo., have issued four booklets in which many types of motors are described and illustrated. One bulletin is devoted to repulsion start induction single phase motors; a second to automatic start induction poly-phase motors; a third to split phase induction motors and the fourth to squirrel cage induction poly-phase motors.

Stokers — The Laclede-Christy Clay Products Company, St. Louis, is circulating a bulletin describing Armour & Company's experience with their stokers. The bulletin is well written and illustrated, and gives much data of value to prospective stoker buyers.

The **U. G. I. Contracting Company**, of Philadelphia, has recently been awarded a number of contracts. They will install an additional carburetted water gas apparatus for the Roanoke Gas Light Company, Roanoke, Va., and will remodel and improve the carburetted water gas sets of the C. H. Geist Company, Glassboro, N. J., and the two sets of the Lewiston Gas Light Company, Lewiston, Me. The Old Colony Gas Company, East Braintree, Mass., has also decided upon extensive improvements to its plant, which will be carried on by the U. G. I. Company. The Queens Borough Gas & Electric Company will have improvements made on an extensive scale; and the Equitable Gas Company of Pittsburgh has made arrangements for the installa-

tion of three U. G. I. automatic controls at its Elrama plant.

TRADE NOTES

NEW SHEET MILL SHEARS

The Youngstown Foundry & Machine Company, Youngstown, Ohio, builders of mill machinery, have recently added to their line a complete set of heavy squaring shears for sheet mills, embodying the latest features of design and construction. These machines are built in 72, 108, 126 and 154-in. sizes. This company has also recently developed a sectional angle straightening machine so constructed that it may be furnished with 7, 8, 9, 11 or 13 rolls as desired. These machines are so built that the number of rolls may be increased readily by the addition of further sections. This feature will undoubtedly prove to be a great advantage over the old type of straightening machine in common use.

WESTINGHOUSE COMPANY MAKES RECORD SHIPMENT OF ELECTRIC LOCOMOTIVES

The third shipment of electrical equipment for the Chilean State Railway, consisting of six complete electric locomotives, the largest shipment of electric locomotives ever made, recently left the East Pittsburgh Works of the Westinghouse Electric & Manufacturing Company. The shipment was valued at \$700,000 and represented a partial fulfillment of the \$7,000,000 contract awarded the Westinghouse International Company by the Chilean State Railways.

Thirty-nine electric locomotives, 15 for road freight service, six for express passenger service and seven for switching service, are to be built by the Westinghouse Company for the Chilean Railways. The six locomotives in the recent shipment are of the road freight type and weigh approximately 103 metric tons each. They are capable of maintaining an average speed of 35 miles per hour when hauling a 770-ton train on any part of the line between Valparaiso and Santiago, except the heavy Tabon grade.

Frey, Brassert & Company, Chicago, have recently taken contracts with the Norton Iron Works, Ashland, Ky., for the relining of one of their hot blast stoves with the Brassert Patented Hot Blast Stove Lining, also with the Belfont Iron Works Company, Ironton, Ohio, for installation of a pig casting machine at their furnace plant."

Dayton Steel Foundry Company, Dayton, Ohio, have just purchased a three-ton Moore Rapid 'Lectromelt furnace for their steel foundry. Their trade has enlarged to the extent that their old fur-

nace equipment will not take care of it and the company is improving its equipment in view of its larger business. The 'Lectromelt furnace here replaces two furnaces of another make.

Frey, Brassert & Company have recently contracted for installation of patented Bacon Waste Heat Boilers at the Bettendorf Company, Bettendorf, Iowa, and at the plant of the Carpenter Steel Company, Reading, Pa.

The Norwalk Iron Works Company, pioneer builders of compressors, manufacturing air and gas compressors for all purposes and also refrigerating machinery, with general offices and works, South Norwalk, Conn., has just opened a Chicago office. It is located at 627 W. Washington Boulevard and is in charge of Mr. L. R. Bremser who for 13 years was associated with the Gardner Governor Company. He is thoroughly familiar with all angles of the compressor business.

The Underfeed Stoker Company of America has received orders from the National Enameling & Stamping Company for all the sheet, pair, and annealing furnaces for their new plant at Granite City, Ill. The same company has received an order from the Newton Steel Company, Newton, Ohio, for a pair furnace for their new plant.

Work has been started by Dwight P. Robinson & Company on the design and construction of an extension to the plant of the American Rolling Mill Company at Ashland, Ky. The extension will include a jobbing and sheet mill, and a galvanizing plant. This is one of several undertakings recently awarded to Dwight P. Robinson & Company.

COMING MEETINGS

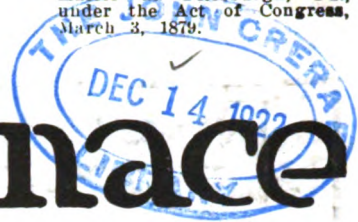
December 4-8 — American Society of Mechanical Engineering, annual meeting in Engineering Societies Building, New York. Calvin W. Rice, 29 West 39th Street, is Secretary.

December 7-13 — National Exposition of Power and Mechanical Engineering at the Grand Central Palace, New York.

January 11-12—American Engineering Council annual meeting headquarters F. A. E. S., 24 Jackson Place, Washington. L. W. Wallace, 24 Jackson Place, Washington, is Secretary.

February 17-22 — Universal Exposition of Inventions and Patents, under the auspices of the Universal Patent Exposition Corporation, Grand Central Palace, New York.

February 19-21 — American Institute of Mining and Metallurgical Engineers annual meeting in Engineering Societies Building, New York. F. F. Sharpless, 29 West 39th Street, is Secretary.



The Blast Furnace *and* Steel Plant

Pittsburgh, December, 1922.

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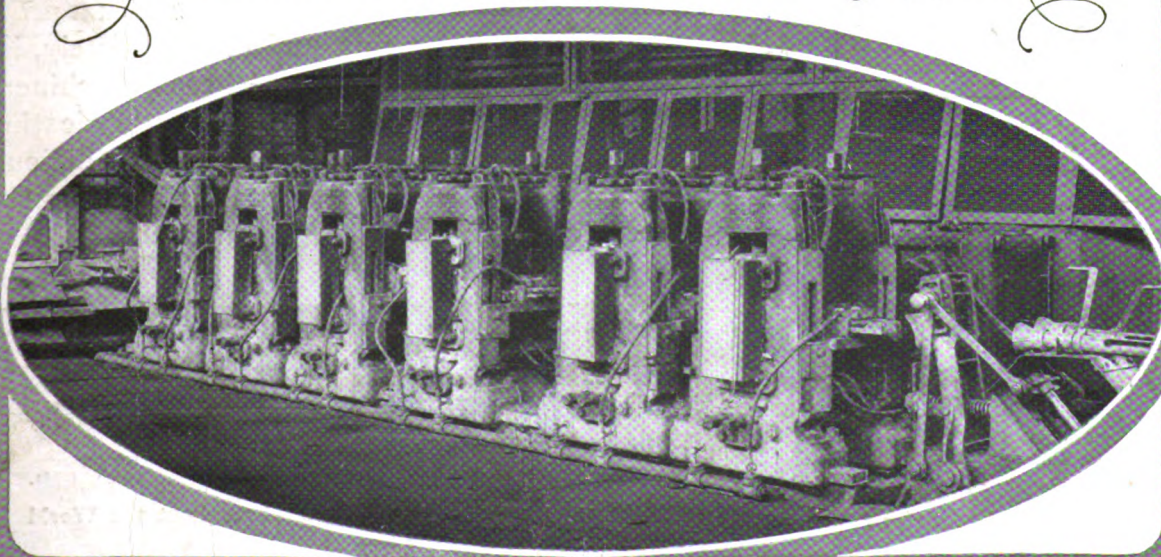
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